Investigating the Contribution of Personality and Neurological Disruption to Postinjury Outcome in Athletes with Mild Head Injury

by

Nicole Barry

A thesis
submitted in partial fulfilment
of the requirements for the degree of
Master of Arts, Psychology

Department of Psychology
BROCK UNIVERSITY
St. Catharines, Ontario

Abstract

Despite the increase in research regarding mild head injury (MHI), relatively little has investigated whether, or the extent to which, premorbid factors (i.e., personality traits) influence, or otherwise account for, outcomes post-MHI. The current study examined the extent to which postinjury outcome after MHI is analogous to the outcome post-moderate or- severe traumatic brain injury (by comparing the current results to previous literature pertaining to individuals with more severe brain injuries) and whether these changes in function and behaviour are solely, or primarily, due to the injury, or reflect, and are possibly a consequence of, one's preinjury status. In a quasi-experimental, test-retest design, physiological indices, cognitive abilities, and personality characteristics of university students were measured. Since the incidence of MHI is elevated in high-risk activities (including high-risk sports, compared to other etiologies of MHI; see Laker, 2011) and it has been found that high-risk athletes present with unique, risk-taking behaviours (in terms of personality; similar to what has been observed post-MHI) compared to low-risk and non-athletes. Seventy-seven individuals (42% with a history of MHI) of various athletic statuses (non-athletes, low-risk athletes, and high-risk athletes) were recruited. Consistent with earlier studies (e.g., Baker & Good, 2014), it was found that individuals with a history of MHI displayed decreased physiological arousal (i.e., electrodermal activation) and, also, endorsed elevated levels of sensation seeking and physical/reactive aggression compared to individuals without a history of MHI. These traits were directly associated with decreased physiological arousal. Moreover, athletic status did not account for this pattern of performance, since low- and high-risk athletes did not differ in terms of personality characteristics. It was concluded that changes in

behaviour post-MHI are associated, at least in part, with the neurological and physiological compromise of the injury itself (i.e., physiological underarousal and possible subtle OFC dysfunction) above and beyond influences of premorbid characteristics.

Acknowledgments

I would not be where I am today without the love, support, and guidance that I have received throughout my academic pursuits. My support system has allowed me to see my full potential, persevere through adversity, and ultimately achieve success—for these reasons I am forever grateful.

To my family—I cannot thank you enough. You have all never ceased to be there for me when I have needed it (despite the fact that many of you are on the east coast!). To my parents—there are no words to describe my appreciation, love, and thanks to you; your unconditional love and unwavering support has allowed me to overcome every challenge that I have faced. To my friends who I consider to be family—thank you. There are so many of you who have endlessly comforted me, supported me, or simply listened to me when I have needed it most. To my Ontario support system—you have all played such a key role in my life over the past few years. I will never forget all of the love and support that I have received from all of you—thank you. I love you all dearly.

To my supervisor, Dr. Dawn Good—thank you for believing in me and seeing my potential. I have learned more from you over the course of my graduate studies than I ever thought imaginable. Your guidance, knowledge, dedication, patience, and persistence are second-to-none. I am truly lucky to have had the opportunity to learn from you—I cannot thank you enough for everything.

I also want to thank my committee members: Dr. Sidney Segalowitz and Dr. Drew Dane. Sid—I will never forget your invaluable guidance and support, and for always taking the time to ask how things were going. Drew—thank you for your vital suggestions and guidance, and for always extending a kind hello in the hallways.

Finally, I would like to extend an enormous thank you to all of the members of the Neuropsychology Cognitive Research Lab—this project would not have been possible without all of you. Words cannot express how thankful I am for all of your dedication, hard work, and patience. I want to acknowledge the hard work and assistance of J.P. Karwowski, John Krzeczkowski, Xiaoyang Xia, Larissa Mazzarella, Laura Murray, Jazmine Rei Que, Nayomi Sathaisingle, Bailee Malivoire, Julia Dvovnikov, Ashley Best, Eryn Hartmier, Chris Turl, and Michael DeGiuli.

I also want to acknowledge all individuals who are living with the effects of a brain injury—may you always persevere through adversity and continually receive the love and support of others.

Table of Contents

List of Tables

List of Figures

List of Appendices

List of Acronyms and Abbreviations

A	Anger
ANOVA	Analysis of Variance
ANS	Autonomic Nervous System
BP	Blood Pressure
BPAQ	Buss and Perry Aggression Questionnaire
CI-R	Revised Competitiveness Index
CPM	Cycles Per Minute
CT	Computerized Tomography
CTE	Chronic Traumatic Encephaolopathy
DTI	Diffusion Tensor Imaging
EDA	Electrodermal Activation
EEG	Electroencephalogram
ELQ	Everyday Living Questionnaire
fMRI	Functional Magnetic Resonance Imaging
GCS	Glasgow Coma Scale
H	Hostility
HR	Heart Rate
HRV	Heart Rate Variability
Hz	Hertz
LHA	Life History of Aggression Scale
LNS	Letter Number Sequencing
LOC	Loss of Consciousness

M	Mean
MC	Modified Competitiveness Questionnaire
MHI	Mild Head Injury
MRI	Magnetic Resonance Imaging
mTBI	Mild Traumatic Brain Injury
MVC	Motor Vehicle Collision
NU	Negative Urgency
OFC	Orbitofrontal Cortex
PA	Physical Aggression
PCS	Post-concussive Symptoms
PM	Premeditation
PSAP	Point Subtraction Aggression Paradigm
PTA	Post Traumatic Amnesia
PU	Positive Urgency
PV	Perseverance
RTP	Return-to-play
SD	Standard Deviation
SDMT	Symbol Digit Modalities Test
SIS	Second Impact Syndrome
SNS	Sympathetic Nervous System
SOQ	Sport Orientation Questionnaire
SS	Sensation Seeking
TBI	Traumatic Brain Injury

TMT-II	Trail Making Test-II
TMT-IV	Trail Making Test-IV
UPPS-P	The UPPS-P Impulsive Behaviour Scale
VA	Verbal Aggression
VMPFC	Ventral Medial Prefrontal Cortex
WAIS	Wechsler Adult Intelligence Scale
WRAT	Wide Range Achievement Test

Investigating the Contribution of Personality and Neurological Disruption to Postinjury Outcome in Athletes with Mild Head Injury

The incidence of nonfatal brain injuries is exceedingly high, reaching upwards of 1.5 to 3.6 million cases in the United States (Centers for Disease Control, 2007). Further, approximately 80 to 90 percent of those injuries are classified as mild (Iverson & Lange, 2009; Ruff, 2011). Specifically, there are reportedly 653 cases per 100,000 of mild traumatic brain injuries (mTBI) in Ontario, Canada annually (Ryu, Feinstein, Colantonio, Streiner, & Dawson, 2009). Additionally, approximately 30 to 50 percent of high-functioning high school and university students have a history of mild head injury (MHI; Baker & Good, 2014; Segalowitz & Lawson, 1995; van Noordt & Good, 2011). For adolescents and young adults, head injuries most commonly occur due to falls, motor vehicle collisions (MVC), and sport-related activities (e.g., Cassidy et al., 2004). In their study, Sosin, Sniezek, and Thurman (1996) reported an incidence of 618 per 100,000 nonfatal injuries annually (all with a loss of consciousness; LOC), with 28 percent of those resulting from MVC and 20 percent occurring from a sport-related activity. Epidemiology studies pertaining to brain injury are generally inconsistent due to differing operational definitions of traumatic brain injury (TBI) and mTBI, in addition to underestimation of injuries.

Athletes are often exposed to the risk of experiencing mTBI (i.e., in terms of concussion), especially in high-risk sports (Gessel, Fields, Collins, Dick, & Comstock, 2007; Noble & Hesdorffer, 2013; Vakil, 2005) such as American football, hockey, and boxing, among others. Sport-related activities serve as one of the leading causes of concussion, and account for 300,000 injuries annually; although this statistic is conservative as it only accounts for injuries that resulted in a LOC (Bazarian, Cernak, Noble-Hacusslein, Potolicchio, & Temkin, 2009). Sport-related concussions account for twenty percent of TBIs that result in a LOC (Meehan & Bachur, 2009). Further, concussions comprise approximately nine percent of all injuries sustained in athletics annually (Zuckerman, Lee, Odom, Solomon, Forbes, & Sills, 2012). However, it is believed that the reported cases of mTBIs annually may be underestimated (Langlois, Rutland-Brown, & Wald, 2006); in their study, Segalowtiz and Lawson (1995) reported that upwards of 80 percent of students with a history of MHI were not admitted to hospital for their injury.

Underestimation of mTBI incidence is assumed for a variety of reasons. First, many individuals with MHI do not seek medical assistance (McCrea, 2008) and many concussed athletes (e.g., 50% of high school football players) do not report their symptoms to their medical staff (McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004). Further, athletes may not be aware of the symptoms of concussion, since reportedly one-third of athletes do not recognize their symptoms after an injury (Meehan & Bachur, 2009). For example, approximately 30 percent of collegiate athletes reported playing a sport with a headache following a blow to the head (Kaut, DePompei, Kerr, & Congeni, 2003). Meehan, Mannix, O'Brien, and Collins (2013) also found that 30.5 percent of athletes had previously sustained an undiagnosed concussion. This is especially problematic as athletes can experience second impact syndrome (SIS) by prematurely returning to sport prior to acute metabolic recovery (Vagnozzi et al., 2008) and resolution of concussive-like symptoms (Cantu, 2009).

Research investigating sport-related concussions has been increasing in recent years as it offers advantages over studying head injuries in other populations. One advantage is that its high incidence of concussion provides an environment to study concussion with ample opportunity. There are also non-concussed controls (typically age-matched, many sport-related experiential variables in common) available to compare to the injured athletes. For athletics, typically the medical staff performs a baseline measure prior to the athletic season, so pre- and postinjury scores can be compared when an athlete sustains a concussion. The sporting season is generally the time of highest risk exposure for athletes – providing a targeted and defined period of time for medical staff and researchers to examine the consequences of injury. Finally, since medical personnel are typically present at the time of injury, there is an opportunity for objective and subjective documentation of the injury. This may improve accuracy of description of the sustained injury and its severity of impact. This aids in understanding the mechanics of concussion and helps to predict outcome and required rehabilitation for the athlete (McCrea, 2008).

The incidence of concussion is particularly high in certain sports; it is repeatedly found that athletes who play ice hockey, football, soccer, rugby, lacrosse, or boxing, often described as ‘high-risk sports’, experience the highest rate of concussion (Bailes, Petraglia, Omalu, Nauman, & Talavage, 2013; Broglio, et al., 2014; Killam, Cautin, & Santucci, 2005; McAllister et al., 2012; Noble & Hesdorffer, 2013). High-risk sports are sports that, due to the nature of the sport, risk for injury is increased. This categorization includes contact sports as well as other risky sports that do not necessarily involve contact (e.g., snowboarding).

In one study, amateur athletes who played ice hockey had the highest incidence of concussion (3.6 per 1000 exposures), whereas at the professional level, the incidence of concussion was highest in both ice hockey (6.5 per 1000 exposures) and rugby (9.05 per 1000 exposures; Tommasone & Valovich McLeod, 2006). Moreover, up to eight percent of high school, collegiate, and professional football players, respectively, sustain a concussion yearly (Guskiewicz, Weaver, Pauda, & Garrett, 2000). Individuals that participated in high-risk sports (i.e., football, hockey, etc.) had a significantly higher incidence of mild head injury than individuals who participated in low-risk sports (i.e., swimming, track and field, etc.) (unpublished data, Neuropsychology Cognitive Research Laboratory, 2014).

It has been found that participation in sports that involve head contact has a significant small to moderate effect on neuropsychological functioning (Belanger, Spiegel, & Vanderploeg, 2010; Dougan, Horswill, & Geffen, 2014). Through their meta-analysis on sport-related concussions, Belanger and Vanderploeg (2005) found that participation in risky sports (e.g., boxing, soccer) had a greater, albeit small, effect on neuropsychological functioning compared to athletes who participated in non-risky sports (e.g., track and field). They noted that high-risk athletes have more exposure to head injury and head contact, and neuropsychological functioning decreases as their exposure increases. It has been recently suggested that these subtle, but significant, neuropsychological impairments in contact athletes may be due to subconcussions, or additive effects of blows to the head without sufficient symptomatology for concussion diagnosis (Bailes et al., 2013; Bazarian, Zhu, Blyth, Borrino, & Zhong, 2012; McAllister et al., 2012; Rabinowitz, Li, & Levin, 2014). Notably, Crisco et al. (2011) stated that an offensive lineman can experience over 1000 subconcussions in one season. McAllister et al. (2012) found that white matter integrity (assessed by diffusion tensor imaging [DTI]) of collegiate football players was significantly decreased from pre- to postseason – implicating a role of detrimental repetitive impacts to the head throughout the course of the athletic season. Likewise, Abbas et al. (2014) found that asymptomatic collision-sport athletes (i.e., high school football players) demonstrated default mode network hyperconnectivity relative to non-collision-sport athletes. In the same study, it was also found that football players exhibited significantly different functional connectivity compared to their own pre-season baseline at the end of the football season. Moreover, Koerte et al. (2012) also identified white matter diffusivity changes from pre- to postseason in university ice hockey players in right precentral regions, the right corona radiate, and the anterior and posterior limbs of the internal fasiculus.

In addition to the nature of high-risk sports, many premorbid/subject-specific factors (i.e., age, sex, years of education) have been shown to moderate the effects of concussions on athletes (e.g., persistence of symptoms, postural stability, neuropsychological performance; Dougan et al., 2014). There are additional premorbid factors, such as personality characteristics of impulsivity or sensation seeking, in high-risk athletes that attract these individuals to gravitate toward, and participate in, these types of sports, thereby increasing their susceptibility to injury. These potential premorbid factors could help explain, or contribute to, the neuropsychological competence observed postinjury and warrants further investigation.

Defining Mild Head Injury/Biomechanical Mechanisms

There are various terms to describe milder head injuries, including MHI, minor head injury, mTBI, and concussion (e.g., Iverson & Lange, 2009; Marshall, 2012). For the purposes of this thesis, previous literature from all classifications of mild head injuries are included. However, in regard to the current sample, the term MHI is used to depict a liberal criterion for self-reported injuries, as described by Kay et al. (1993; Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the ACRM – see below).

There is now a general understanding of the biomechanics and neurophysiology of impact injuries and, as a result, researchers have been able to predict injury outcome to a certain degree (McCrea, 2008). Cognitive, behavioural, and physiological deficits post-concussion have been observed repeatedly in athletes resulting from the acute metabolic changes associated with biomechanical forces (McCrory et al., 2009; Vakil, 2005).

The diagnosis criterion for a MHI requires an alteration in an individual's state of consciousness, but not a loss of consciousness (Kay et al, 1993; McCrea, 2008). Most commonly, concussions are due to a blow to the head, neck, face, but can also occur from contact elsewhere on the body that transmits sufficient impulse to the brain. The resulting rotational and/or acceleration-deceleration forces can cause tensile strain damage and/or axonal sheering, among other neurophysiological changes (Hall, Hall, & Chapman, 2005). These acute neuropathological changes can produce, or accompany, functional deficits (McCrory et al., 2005) as reflected in various cognitive, behavioural, affective, and physiological symptoms (McKee, Daneshvar, Alvarez, & Stein, 2013).

Pathophysiologically, upon impact, a neurometabolic cascade ensues (Meehan & Bachur, 2009). With disruption to the neuronal membranes, there is an immediate and arbitrary exchange of ions resulting in neurotransmitter release and depolarization. Acutely, an efflux of potassium and an influx of calcium ensue when excitatory neurotransmitters bind to *N*- methyl-$_{D}$- asparate (NMDA) receptors. Thus, the sodium-potassium pump attempts to restore normal cellular physiology and requires higher than normal levels of adenosine triphosphate (ATP), which increases glucose metabolism. There is a significantly insufficient amount of energy, as this increase in glucose metabolism co-occurs with decreased blood flow. This is termed an 'energy crisis' and may render the individual more susceptible to postinjury impairments, and subsequently less able to appropriately respond to subsequent injury (Giza & Hovda, 2001). Following the acute hypermetabolism, metabolism decreases and calcium levels remain elevated, which can inhibit oxidative metabolism in mitochondria or lead to cell death as well as energy failure and hyperglycolysis. Intracellular magnesium levels are also acutely diminished after TBI, potentially resulting in further neuronal dysfunction (Giza & Hovda, 2001).

On a neuronal level, further changes can occur such as oxidative stress, irreversible cell damage or death, and damage to the neurofilaments and microtubules disrupting neural connectivity (Marshall, 2012). A concussion may cause cholinergic neuron degeneration and alterations in choline acetyltransferase activity (Gorman, Fu, Hovda, Murray, & Traystman, 1996). When individuals who have sustained a concussion attempt to perform a cognitive task, functional magnetic resonance imaging (fMRI) has shown acutely decreased cerebral activity in selective neuronal circuits compared to noninjured, matched controls (Marquez de la Plata et al., 2011). Henry, Tremblay, Boulanger, Ellemberg, and Lassonde (2010) identified enhanced levels of glutamate and N-acetylaspartate in athletes' post-concussion compared to controls. Furthermore, the enhanced levels of glutamate and N-acetylaspartate positively correlated with self-reported post-concussive symptoms (PCS). Neuronal, biomechanical and metabolic changes that occur at the time of injury are generally associated with the observable cognitive, behavioural, and physiological effects that occur postinjury.

Effects of Mild Head Injury

Head injuries occur on a continuum of severity from mild to catastrophic in nature (Iverson & Lange, 2009). The term concussion is synonymous with mild traumatic brain injury (mTBI) and is typically the preferred term when referring to sport-related mTBIs. Mild head injury (MHI) encompasses both aforementioned terms and includes a wider definition of injury. Unlike other head injuries, when a TBI is sustained, it is not only a single location of impact that is affected; rather, it is typically diffuse. Thus, one blow to the head may result in many physiological and psychological deficits (Torkelson, Jellinek, Malec, & Harvey, 1983). It has been well documented that cognitive, behavioural, affective, and physical impairments can occur as a result of moderate or severe head injuries (e.g., Iverson & Lange, 2009; Stambrook, Moore, Peters, Deviaene, & Hawryluk, 1990). Whether such impairments occur postinjury in more mild cases remains controversial (Ponsford, Cameron, Fitzgerald, Grant, & Mikocka-Walus, 2011). Despite the fact that the majority of individuals who have previously sustained a milder head injury are high functioning, there is substantial supporting evidence that milder injuries (i.e., mTBI, MHI) can result in various long-term impairments postinjury. These impairments may be similar to those that can occur after severe or moderate TBI (e.g., cognitive challenges, lowered physiological arousal, 'personality' alterations), albeit generally quite subtle and less detrimental (e.g., Baker & Good, 2014; Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg, 2005; McCrory et al., 2005; Vakil, 2005; van Noordt & Good, 2011).

The various impairments following a sport-related injury that can occur are correlated with the biomechanics of the injury and disruption to vulnerable brain areas; for instance, the frontal lobes (especially the orbitofrontal cortex - OFC) and the temporal lobes (especially the medial temporal lobes) are particularly susceptible to impact (Morales et al., 2007). These areas are in direct proximity to bony perturbances in the skull, specifically the cribriform plate which supports the inferior regions of the frontal lobe and is an especially rough area of the skull (Bigler, 1999; Umile, Sandel, Alavi, Terry, & Plotkin, 2002). Additionally, the brain stem has been identified as a vulnerable area of shear stress in mTBI (e.g., Zhang, Yang, & King, 2004) - this may be important in explaining physiological underarousal that has been observed post-MHI (e.g., Baker & Good, 2014) due to the involvement of the brainstem in autonomic nervous system (ANS) regulation (e.g., Benarroch, 1993).

These brain areas are also vulnerable to particular mechanisms of injury. For example, Delaney, Peni, and Rouah (2006) reported that the temporal lobes were particularly vulnerable to injury from a concussion in soccer largely due to oncoming balls that are out of the player's field of vision. In these cases, the player likely does not engage the neck as he/she would normally when hitting the ball with the front of his/her head. Subsequently, the neck continues to accelerate in the direction of the ball after contact has been made, often resulting in an alteration of consciousness. Injury to the brain in these areas may partially explain various impairments observed postinjury, including potential personality changes observed in athletes, as many of the impairments that individuals report postinjury are localized in these particularly vulnerable areas (Bigler, Andersob, & Blatter, 2002; Blair, 2004).

As aforementioned, a concussion typically results in deficits of cognitive and neurological functioning (e.g., McCrory et al., 2005). Acute physical symptoms of concussions can consist of: fatigue, slowness, headache, pressure in the head, balance problems, dizziness, coordination problems, vision difficulties (e.g., glassy-eyed, seeing stars or flashing lights, double-vision), ringing in the ears, slurred speech, nausea, and LOC. There are also associated acute cognitive symptoms such as memory and attention difficulties (e.g., recollection, distraction, loss of concentration), clouded consciousness (e.g., haziness, stunned feeling, confusion), and affective symptoms, such as mood and personality changes (e.g., irritability, lability, displaying inappropriate emotions; McCrory et. al., 2005). At two and 48 hours post-mTBI, Echemendia, Putukian, Mackin, Julian, and Shoss (2001) found that noninjured controls performed significantly better on a neuropsychological battery. However, importantly, the injured and noninjured groups did not differ on any measures at baseline or after 48 hours.

Acute symptoms resulting from sport-related concussions generally subside within seven to 10 days (McCrory et al., 2009). However, all individuals do not follow the same trajectory of recovery. Approximately 10 percent of concussed athletes require longer than a week to return to baseline (and even at 90 days postinjury demonstrated verbal fluency challenges relative to controls; McCrea et al., 2003). In most cases, cognitive deficits subside after three months (Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg, 2005) and physical symptoms subside within weeks (McCrea, 2008). Moreover, PCS recovery generally coincides with cognitive recovery (Bleiberg et al., 2005). Greater cognitive sequelae were also found to be associated with multiple head injuries (Belanger and Vanderploeg, 2005). If an individual has sustained at least one concussion previously, susceptibility for subsequent injury significantly increases and symptoms are more likely to persist (Abrahams, McFie, Patricios, Posthumus, & September, 2013; McKee et al., 2009; Valovich McLeod, Bay, Lam, & Chhabra, 2012).

If an athlete returns to play before all symptoms have resolved, SIS may occur. That is, if the athlete sustains a second injury prior to symptom resolution of the first, serious long-term effects, including death (Echemendia et al., 2001), can occur. Repetitive injury can also result in Chronic Traumatic Encephalopathy (CTE), which is associated with changes in personality, behavioural disturbances, memory impairment, speech problems, and Parkinsonism (McKee et al., 2009). Other detrimental memory dysfunction or cognitive impairments can be observed after repetitive injury, as is often seen in long-time boxers (Guskiewicz, Marshall, & Bailes, 2005; Spear, 1995). With regards to returning-to-sport postinjury, medical staff should be conservative in making return-to-play (RTP) decisions to avoid additional, detrimental effects (Herring et al., 2011; McCrory et al., 2013).

There is some evidence to suggest that particular individuals may be susceptible to experiencing long-term neurocognitive challenges post-mTBI - at least 15 percent of individuals who sustain a sport-related concussion experience persistent cognitive problems (Carroll et al., 2004). Dean and Sterr (2013) found that individuals with a history of mTBI and persistent PCS demonstrated decreased working memory capacity (via the n-back task) and processing speed (via the Paced Visual Serial Addition Task; Gronwall, 1977) than individuals with a history of head injury without persistent PCS and health controls, even up to one year postinjury. Strain et al. (2015) stated that prior sport-related concussion with LOC increases the risk for developing mild cognitive impairment as well as hippocampal atrophy. Likewise, Ponsford et al. (2011) stated that individuals who previously sustained a mTBI displayed poorer visual memory three months postinjury compared to healthy controls. Bernstein (2002) also reported that individuals who self-reported sustaining a previous concussion performed worse on the Digit Symbol subscale of the Wechsler Adult Intelligence Scale-Revised (WAIS-R; a task reflecting working memory and processing speed, among other neurocognitive domains; Wechsler, 1981) and a visual memory task; however, sample sizes were quite small. Moreover, De Beaumont et al. (2009) investigated long-term neuropsychological functioning years after sport-related concussion(s). It was found that retired athletes with a history of concussion, on average 34.74 years prior, displayed decreased episodic memory and response inhibition compared to retired athletes without a history of concussion. However, Bigler and Brooks (2009) stated that individuals with a history of mTBI generally score within normal limits on conventional neuropsychological testing. Others, including Rohling, Binder, Demakis, Larrabee, Ploetz, and Langhinrichsen-Rohling (2011) in a meta-analysis, have also found no significant differences on neuropsychological functioning three months post-mTBI compared to healthy controls.

In addition to cognitive alterations, various personality changes have been observed postinjury, including changes in aggression (including anger), impulsivity, apathy, empathy, and neuroticism (Henry 1994; Mendez, Owens, Jimenez, Peppers, & Licht, 2013; Rochat, Beni, Billeux, Azouvi, Annoni, & Van der Linden, 2010). These personality changes have been documented to be persistent and long lasting (McCrea et al., 2009). Personality changes, including increases in impulsivity and aggression, are often associated with frontal lobe dysfunction (Diamond & Magaletta, 2006; Mateer, 1999). In particular, injury to the orbital-frontal cortex (OFC) is associated with increased impulsivity (Cattran, Oddy, & Wood, 2011) and, specifically, injury to the ventromedial prefrontal cortex (VMPFC) is associated with increased aggression (Diamond & Magaletta, 2006; Grafman, Schwab, Warden, Pridgen, Brown, and Salazar, 1996). A study was performed by Goswami et al. (2015) that investigated fronto-temporal correlates of impulsivity and aggression in retired football players with a history of multiple concussions. Through the use of magnetic resonance imaging (MRI), it was found that the retired athletes demonstrated cortical thinning of the anterior temporal lobes and increased resting-state functional connectivity between the OFC and the anterior temporal lobes compared to healthy controls. Furthermore, there was a negative correlation between OFC cortical thickness and aggressive/impulsive behaviour on a go/no-go task in the retired athlete group. In addition, there was a negative correlation with uncinate fasciculus (a white matter tract that connects the OFC with the anterior temporal lobe; Schmahmann et al., 2007) axial diffusivity and aggressive/impulsive behaviour. This provides evidence of the neural dysfunction experienced after sustaining multiple concussions is associated with increased impulsivity and aggression.

Previous researchers have also documented a link between aggression and history of TBI; individuals who are living with the effects of TBI often have high levels of aggression (Andrews, Rose, & Johnson, 1998; Baugh et al., 2012; Dryer, Bell, McCann, & Raunch, 2006; Max, Robertson, & Lansing, 2001; Oquendo, Friedman, Grunebaum, Burke, Silver, & Mann, 2004; Tateno, Jorge, & Robinson, 2003; Wong, 2011). Dryer et al. (2006) found that TBI patients displayed significantly higher rates of impulsive verbal aggression than controls. However, the nature of the aggressive traits is not generally specified. Ferguson and Coccaro (2009) found that when compared to non-injured controls, individuals who had previously sustained a mild or moderate TBI had significantly higher aggression scores, as indicated by the Life History of Aggression questionnaire (LHA; Coccaro, Berman, & Kavoussi, 1997). Further, it was reported that their levels of aggression had increased since their injury; however, it could not be determined whether the heightened aggression was solely due to their injury, or whether aggression was exaggerated postinjury.

One study investigated both premorbid and postinjury levels of impulsive aggression in individuals with a history of severe TBI. Of the 45 individuals with a history of severe TBI, 26 displayed impulsive aggression, 14 of which had a premorbid history of impulsive aggression; only five individuals out of the 19 in the non-impulsive aggressive group had a premorbid history of impulsive aggression. Further, at the time of testing, the impulsive aggressive group was significantly more impulsive (as indicated by the Barratt Impulsivity Questionnaire; Patton, Stanford, & Barratt, 1995) and more antisocial (via the LHA; Coccaro et al., 1997) than the non-impulsive aggressive group. However, there were no differences on the Buss and Perry Aggression Questionnaire (BPAQ; Buss & Perry, 1992) or any neurocognitive measures.

It has been repeatedly found that there is an association between aggression and impulsivity (Ferguson & Coccaro, 2009). Houston and Stanford (2005) found that individuals who were highly impulsive also had higher levels of trait aggression than non-impulsive controls. Likewise, it has been found that individuals living with the effects of TBI generally have higher levels of both impulsivity and aggression than uninjured controls (Collins, Pastorek, Tharp, & Kent, 2012). Impulsivity postinjury can coincide with a multitude of other negative attributes, including poor decision-making, impatience, poor judgment ability, as well as being short-tempered, and demonstrating elevated verbal or physical aggression, and increased irritability (e.g., McAllister, 2008; van Noordt & Good, 2011; Wood, 2001).

It has been reported that poor impulse control is a common feature post-TBI (e.g., Kolitz, Vanderploeg, & Curtiss, 2003; McAllister, 2008). A link between TBI and impulsivity has been repeatedly reported (e.g., McHugh & Wood, 2008; Rochat et al., 2010; Votruba et al., 2008). Furthermore, the constructs that underlie impulsivity, including lack of premeditation, lack of urgency, sensation seeking, and lack of perseverance are also generally negatively affected (Kolitz et al., 2003; Rochat et al., 2010; Whiteside & Lynam, 2001). Olson-Madden, Brenner, Corrigan, Emrick, and Britton (2012) found an association between impulsivity and TBI; individuals may seek out exciting or, at times, dangerous situations to feel stimulated. Cattran et al. (2011) also reported that post-TBI, individuals commonly exhibit impulsive and disinhibited behaviours. However, in all aforementioned studies, patients' specific premorbid scores were not reported.

Baseline/Neuropsychological Testing in Sport

If there is a medical staff associated with an athletic team, they generally take baseline cognitive and physical measures of all athletes at the beginning of their respective seasons. After the athlete is suspected to have sustained a concussion, the athlete will take another test and the baseline and postinjury scores will be compared. Typically, when the postinjury score is similar to the preinjury score, an athlete will begin a RTP (return-to-play) program (Kelly et al., 2012).

A RTP protocol is a stepwise guideline procedure that involves activities that the athlete must perform prior to returning to sport. The procedure is as follows: no activity and only rest, light aerobic exercise, basic sport specific activities, sport specific drills without any contact, drills with contact and, finally, game play. After each step, the athlete must be asymptomatic for 24 hours until proceeding to the next step (McCrory et al., 2009). If an athlete experiences symptoms, they must revert to the previous step. Throughout the RTP process, an athlete's current scores on various cognitive, neuropsychological, or physical tests should continue to be compared to their preinjury baseline scores (Doolan, Day, Maerlender, Goforth, & Gunnar Brolinson, 2012). This stresses the importance of valid preseason baseline testing in sport.

Neuropsychological tests are amongst the most reliable in detecting changes postinjury, and have the ability to identify changes that conventional neuroimaging cannot (i.e., MRI, computed tomography [CT]; Williams, Rapport, Hanks, Millis, & Greene, 2013) – especially residual cognitive impairments of an injury (Slobounov, Gay, Johnson, & Zhang, 2012). Thus, these tests have become standard administration protocol pre- and postinjury to athletes. When neuropsychological assessments cannot be used, concussions are generally assessed by behavioural, physical, and cognitive complaints of symptoms postinjury (Hall et al., 2005). That said, most (i.e., 85%) medical professionals who make RTP decisions for athletes use baseline and postinjury neuropsychological test scores to help make their decisions (McLeod & Leach, 2012). There is some debate as to whether the measures used to generate these scores are sensitive enough to detect the subtle differences that may underlie cognitive and physiological changes postinjury (Barr & McCrea, 2001). However, when they are administered as when a battery of tests, accuracy significantly improves (Register-Mihalik, Guskiewicz, Mihalik, Schmidt, Kerr, & McCrea, 2012). Unfortunately, many baseline tests do not include physiological measures, which could be beneficial as possible indices of MHI, and improve accuracy of assessment.

In addition to the varying sensitivity of measures, it has been found that the baseline scores of athletes have substantial variability (Valovich McLeod et al., 2012). One newfound problem that may be contributing to these differences is that some athletes purposely perform poorly on baseline measures (Erdal, 2012). Erdal (2012) found that eight percent of athletes could successfully intentionally perform poorly on baseline measures without detection by validity measures. This is problematic, as when athletes sustain a concussion, their postinjury scores will appear to resemble their preinjury scores; as a result, they may return to sport before they are fully recovered. Another contributor to baseline variability is individual differences; there are premorbid factors that influence the performance levels on these tests (Ponsford et al., 2000).

Premorbid Factors and Subsequent Postinjury Outcomes

The behavioural outcome post-TBI is likely a reflection of a combination of pre-existing physiological and psychological (e.g., personality) factors in addition to the trauma and pathology ensued due to the injury (Parker, 1996; Prigatano, 1999). Therefore, it is important to consider premorbid factors associated with TBI and the subsequent coping and recovery variations postinjury. If identified, better predictions of future adjustment and adaptive functioning after sustaining a head injury may be possible (Sela-Kaufman, Rassovky, Agranov, Levi, & Vakil, 2013).

As noted, premorbid personality is a potential moderator of outcome postinjury. Sela-Kaufman et al. (2013) investigated whether personality factors predicted psychological, social, and occupational functioning postinjury in persons with moderate to severe TBI. Premorbid personality was tested via parent or relative questionnaires, using the “Big Five” dimensions of personality (Costa & McCrae, 1992). It was found that the relationship between injury severity (as indicated by the Glasgow Coma Scale [GCS; Teasdale & Jennett, 1974], post-traumatic amnesia [PTA], and loss of consciousness [LOC]) and occupational functioning postinjury varied as a function of particular personality traits—namely neuroticism, conscientiousness, and extraversion. Individuals scoring higher on these personality traits had a more successful occupational outcome. Additionally, Cattran et al. (2011) found that demonstrating better emotional regulation and higher motivation predicted successful social and behavioural outcome one-year postinjury, as indicated by the Mayo Portland Adaptability Inventory-3 (Malec, Kragness, Evans, Finlay, Kent, & Lezak, 2003). Therefore, factors other than severity of injury, such as premorbid personality traits, may have an influence on postinjury outcome.

Another pre-existing factor that may influence performance is sex. It has been found that males and females differ on baseline and postinjury tests, such that females have been shown to significantly outperform males on baseline verbal memory tests, while males significantly outperform females on tests of spatial memory (e.g., Covassin, Swanik, Sachs, Kendrick, Schatz, Zillmer, & Kaminaris, 2006). Furthermore, it is often found that females report significantly worse symptoms postinjury, including headache, fatigue, irritability, feeling more emotional, feeling slowed down, nervousness, sadness, sleep difficulty, and difficulty concentrating (e.g., Hall et al., 2005). Furthermore, Valovich McLeod et al. (2012) and others (e.g., Dougan et al., 2014) have found that male high school athletes scored significantly lower than female high school athletes on neurocognitive measures, such as the Sport Concussion Assessment Tool-II (SCAT2). Others, (e.g., Ponsford et al., 2011) have not found any significant sex differences in regard to outcome post-MHI.

It has also been suggested that particular traits may lead certain individuals to be more susceptible to injury. In a review, Finnoff, Jelsing, and Smith (2011) reported various risk factors for concussion and risk factors for poorer outcomes postinjury. Upon review, it was found that female gender, fatigue, and a history of prior concussion increased risk of sustaining a concussion. Furthermore, there was weak support for particular genetic factors as risk factors for concussion, including a G-219T polymorphism in the APOE promoter region and a $_{T}{}^{Ser}53^{Pro}$ polymorphism on the $_{T}$ gene; however, further research should be done to investigate these factors as this area of research is preliminary. In terms of risk factors for poorer outcome postinjury, it was found that female gender, prior concussion, pre-concussion anxiety or depression, pre-concussion learning disorder, pre-concussion migraine headaches, PTA, younger age, and excessive postinjury exercise lead to worse outcomes.

In a similar study, Abrahams et al. (2013) performed a meta-analysis that investigated risk factors for sport-related concussion. Ten studies demonstrated that women were more at risk for sustaining a concussion than men in various sports including soccer, basketball, and softball (compared to men's baseball). This is possibly attributed to women having less neck strength and smaller head mass than men; increased neck strength may help to lessen acceleration-deceleration forces. However, an alternative explanation is that women are more willing to report injuries. Alternatively, four studies stated that males have a higher incidence of concussion. These studies indicated that in sports such as ice hockey, lacrosse, American football, and alpine sports, incidence of concussion was higher for males. Additionally, it has been reported that men tend to be more impulsive and aggressive in sport (Abrahams et al., 2013), and more likely to take greater risks (e.g., Booth, Cardona-Sosa, & Nolan, 2014 – this may be a learned behaviour); thus, personality may account for more of the variance in incidence of concussion than sex.

All individuals, regardless of sex, who engaged in more aggressive behaviours, had a higher incidence of concussion (Abrahams et al., 2013). Rutter (1984) stated that individuals, especially children, who have experienced a TBI generally have more 'risk-taking' characteristics compared to individuals who have not. For example, Rutter (1984) found via parent questionnaires at the time of injury, that children who have sustained a concussion tended to be aggressive, impulsive, and attention-seeking. Therefore, there is some evidence that particular personality characteristics predispose some individuals to sustain a concussion and that changes in function attributed to the sequelae of concussion may also be associated with preinjury status.

Abrahams et al. (2013) reported that body checking in ice hockey increases risk of concussion. Similarly, Emery et al. (2014) compared the incidence of concussion of youth contact hockey leagues in Alberta to youth hockey leagues in Quebec that were non-contact. They found that allowing contact in hockey leagues for 11 and 12 year olds increased the incidence of concussion by 3.88 times and severe concussion by 3.61 times. Furthermore, individuals who had positive attitudes towards body checking (i.e., demonstrating that they condoned aggressive behaviours in sport) had an increase of incidence of concussion by 0.99 times and an increased incidence of severe concussion by 2.58 times compared to individuals who had a negative attitude toward body checking. While these statistics may be a function of the nature of contact sports, aggression may be associated with the incidence of sport-related concussions. For example, Thompson and Morris (1994) found that elevated outwardly directed anger, decreased attention, and increased stressful life events increased susceptibility to injury (not exclusively concussion) in high school football players.

To complicate matters, it has been found that high-risk athletes generally have higher levels of particular personality traits that may lead them to play riskier sports wherein injury (e.g., concussion) is likely (Kerr, 2014). For this reason, in the current study, participants were categorized into one of three categories based on athletic status—high-risk, low-risk, or non-athlete—in attempts to capture possible differences in premorbid, risky personality. In fact, as aforementioned, the frequency of concussion in high-risk sports is greater than that in low-risk sports (e.g., Gessel et al., 2007). It has been reported that high-risk athletes have elevated levels of sensation seeking (a subcomponent of impulsivity) compared to low-risk and non-athletes (Cronin, 1991; Jack & Ronan, 1998; Potgieter & Bisschof, 1990; Rowland, Franken, & Harrison, 1986; Zuckerman, 1983). Levels of particular personality traits, including sensation seeking and impulsivity, were investigated in female athletes. Interestingly, female high-risk athletes who engaged in recreational sports had the highest levels of endorsed sensation seeking and impulsivity, followed by high-risk professional female athletes. Low-risk female athletes had significantly decreased levels of sensation seeking and impulsivity compared to both high-risk athlete groups. Notably, male athletes were not included in the study (Cazenave, Le Scanff, & Woodman, 2007). Kerr (1991) suggested that high-risk athletes are generally arousal-seekers compared to individuals who choose to engage in sports that are less risky. Thus, this seeking of arousal is reflected by sensation seeking/impulsive personality traits. Zuckerman (1983) also stated that arousal-/stimulation seeking primarily underlies the personality trait of sensation seeking.

Physiological arousal is typically measured by means of respiration, electrodermal activation, and heart rate (Craig, 1968; Lazarus, Speisman, & Mordkoff, 1963). Arousal has been suggested as a principal biological mechanism of impulsivity, such that impulsive individuals are generally underaroused at rest compared to individuals who have lower levels of impulsivity (Barratt, 1985; Eysenck & Eysenck, 1985; Humphreys & Revelle, 1984; Mathias & Stanford, 2003). Also, individuals who are impulsive have greater physiological arousal in response to stimulation than individuals who are not (Houston & Stanford, 2001; Mathias & Stanford, 2003).

Similarly, it has been observed that individuals who have sustained a moderate-to-severe head injury demonstrate physiological underarousal compared to individuals who have not sustained any brain disruption (Hopkins, Dywan, & Segalowitz, 2002). This relationship has also been found in individuals who have experienced an alteration in consciousness more mild in nature (Baker & Good, 2014; van Noordt & Good, 2011). Lower physiological arousal may help to explain the differences in personality, in particular impulsivity, that have been observed postinjury in individuals who have experienced brain dysfunction. This relationship warrants further investigation.

There also may be differences in levels of aggression in athletic groups. In a meta-analysis, Sonderlund et al. (2014) identified 10 studies that reported increased levels of particular risk-taking behaviours (i.e., alcohol use) and elevated levels of aggression in athletes compared to non-athletes. Ziaee, Lotfian, Amini, Mansoournia, and Memari (2012) found that boys involved in Japanese martial arts endorsed higher levels of reactive aggression than boys involved in swimming. Similarly, other studies have reported differences in aggression in contact sport athletes compared to non-contact sport athletes (e.g., Ahmadi, Besharat, Azizi, & Larijani, 2011; Tucker & Parks, 2001). Using the Point Subtraction Aggression Paradigm (PSAP; e.g., Cherek, 1981), Huang, Cherek, and Lane (1999) observed that contact sport adolescent male athletes demonstrated elevated levels of aggression compared to non-contact sport athletes. Significant differences have also been found in levels of overall aggression between athletes and non-athletes (Lenzi, Bianco, Milazzo, Placidi, Castrogiovanni, & Becherini, 1997; O'Brien, Kolt, Martens, Ruffman, Miller, & Lynott, 2012; Rahimizadeh, Arabharmi, Mizany, Shahbazi, & Bidgoli, 2011). However, Lemieux, McKelvie, and Stout (2002) reported no differences in hostile aggression between athletes and non-athletes. In their study, though, there were differences in hostile aggression based on the physical size of the athletes; such that bigger athletes endorsed significantly elevated levels of hostile aggression compared to smaller athletes (Lemieux et al., 2002). In another study, a group of Brazilian athletes and non-athletes were compared in terms of personality; the athlete group displayed significantly higher levels of endorsed disinhibition, irritability, and aggressiveness, among other personality variables (Bara Filho, Scipiao Ribeiro, & Garcia, 2005). Others have not found any differences in endorsed aggression between various athletic groups (Reza, 2012) or contact level in sport (Keeler, 2007).

Coulomb-Cabagno and Rascale (2005) considered levels of aggression in female and male athletes and based on different levels of competition. It was found that male athletes displayed higher rates of aggressive acts than female athletes. Further, regardless of sex, aggressive acts increased as a function of level of competition; such that athletes in higher levels of competition displayed increases in aggressive acts. In addition to sex and level of competition, there may be other environmental factors that contribute to the level of aggression that an athlete has. Grossman and Hines (1996) observed that European-born professional hockey players displayed fewer aggressive acts than North American-born professional hockey players. It is important to mention that history of previous head injury was not reported in any aforementioned studies, and thus could be a potential confounding variable.

Another personality trait that must be considered as a risk factor for concussion is competitiveness. McCrory et al. (2009) stated that aggression and competitiveness should not be discouraged from sport, but that organizers should be wary of violence that may ensue leading to risky situations wherein athletes may sustain injuries. Competitiveness has been defined as the 'need to win' in interpersonal relations (Gill & Deeter, 1988; Smither & Houston, 1992). Athletes generally endorse higher levels of competitiveness than non-athletes (e.g., Kang, Gill, Acevedo, & Deeter, 1991). Further, 29 studies previously found that the incidence of concussion was significantly increased in game play compared to practice (Abrahams et al., 2013). Effort and competitiveness are generally increased in game play, potentially increasing risk of injury for athletes. However, little-to-no previous research has directly investigated the association between competitiveness and concussion.

Current Study

Despite the fact that the focus for some research studies has been to investigate the sequelae of MHI, a definitive consensus has not been reached regarding the potential cognitive, behavioural, and physiological deficits postinjury. Further, little research has investigated whether, or the extent to which, premorbid factors moderate, and otherwise account for, outcomes post-concussion; specifically, if the changes in function post-concussion are solely, or primarily, due to the injury, or if they are associated with preinjury status. In addition, it remains controversial whether particular characteristics increase susceptibility to sustain a MHI. The current study was designed to investigate whether the sequelae post-sport-related concussion is analogous to sequelae observed post-moderate to severe TBI and/or non-athletes with MHI; this was done by comparing results of the current study (i.e., individuals with MHI) with literature pertaining to more severe injuries). Further, it aims to identify premorbid factors (e.g., particular personality traits, pre-season capacity) that may moderate performance outcome observed postinjury.

The primary objective of the study was to investigate the influence of premorbid characteristics (i.e., personality characteristics) on outcomes (i.e., physiological, cognitive, and behavioural alterations) post-MHI. In a quasi-experimental longitudinal study, cognitive abilities, personality characteristics, and physiological activity of high-risk athletes, low-risk athletes, and non-athlete controls were compared at approximately pre- and post- athletic season. Participants were categorized based on athletic status since high-risk athletes generally have riskier personality characteristics (e.g., Zuckerman, 1983) and sustain more MHIs (e.g., Abrahams et al., 2013) than low-risk and non-athletes. Participants completed a battery of neuropsychological tests, personality measures, and a questionnaire regarding history of concussion (as well as demographic details) at two separate time points (pre- and post-athletic season in attempts to capture pre- and postinjury measurements). Physiological indices (heart rate [HR], electrodermal activation [EDA], blood pressure [BP], and respiration) were also measured.

Hypotheses:

1) It is expected that high-risk sports will be associated with more concussions.
2) It is expected that individuals with a history of MHI, regardless of athletic status (i.e., non-athlete, low-risk athlete, or high-risk athlete) will experience cognitive challenges (i.e., slower processing speed and impaired working memory, mental flexibility, and attention) relative to their non-injured cohort.
3) It is expected that compared to individuals who have not sustained a MHI, individuals who have sustained a MHI will demonstrate increased levels of particular personality traits (i.e., impulsivity, aggression, and competitiveness) postinjury, regardless of athletic status. Moreover, it is expected that high-risk

athletes will endorse riskier personality characteristics compared to low-risk and non-athletes and that individuals who endorse elevated levels of aggression, impulsivity, and competitiveness, will be associated with more concussions, regardless of athletic status.

4) Similar to results found in other studies in our laboratory (e.g., Baker & Good, 2014; van Noordt & Good, 2011), it is hypothesized that individuals who sustain a concussion during the season, or have previously sustained a MHI will have lower physiological arousal (i.e., decreased HR, EDA, BP and respiration) compared to individuals without a history of head injury.
5) Further, it is expected that individuals who endorse elevated levels of aggression and impulsivity will demonstrate lower arousal, but that MHI will account for decreased physiological arousal over and above personality characteristics.
6) Of particular interest will be the comparison of individuals' personality traits pre- and postinjury, and their influence on physiological and cognitive performance. It was expected that pre-season status would predict post-season outcome, and that MHI status would account for changes post-season over and above pre-season status (i.e., sustaining a MHI during the season will uniquely account for additional variance in physiological arousal over and above pre-season status).

Methods

Participants

In total, 77 participants (*M* age = 21.01, *SD* = 2.752) completed the pre-season testing session. Participants were recruited via the Brock University Psychology Department Research Pool (SONA), advertisement posters at Brock University (see

Appendix A), and standardized e-mails to various coaches at Brock University. For compensation, participants had a choice to receive a $20.00 gift card to Cineplex Odeon© (i.e., five dollars for every 30 minutes of participation) or two research participation credits (i.e., 0.5 credit for every 30 minutes of participation). It is important to note that participants were not recruited on the basis of head injury status to avoid the possibility of 'diagnosis threat' (see Suhr & Gunstad 2002; 2005); i.e., it has been found that participants with a history of head injury may perform poorer on cognitive and neuropsychological measures if they are aware that a variable of interest is MHI status. Instead, participants were told that the study would investigate "Individual Differences Between Athletes and Non-athletes". At the time of debriefing, participants were informed of the true nature of the study (i.e., that head injury was a primary variable of interest).

Thirty-one participants in the pre-season sample were male (40.3%) and 32 individuals self-reported a history of MHI (41.6%). In terms of athletic status, 24 individuals were identified as non-athletes (31.2%), 29 participants were classified as low-risk athletes (37.6%), and 24 participants were classified as high-risk athletes (31.2%). Athletes were classified based on the self-reported primary sport that they currently played (recreationally or competitively). Of the 53 athletes, 18 reported currently playing sports recreationally and 35 reported currently playing sports competitively (i.e., in a competitive league). A list of sports and associated frequencies can be found in Table 1. Of the individuals who self-reported no history of MHI (M age = 21.04, SD = 2.91), 14 were male (31.1%), 18 were non-athletes (40.0%), 21 were low-risk athletes (46.7%), and five were high-risk athletes (11.1%). In terms of the individuals who self-reported a history of MHI (*M* age = 21.13, *SD* = 2.56), 17 were male (53.1%), six were non-athletes (18.8%), eight were low-risk athletes (25.0%), and 18 were high-risk athletes (56.2%).

Table 1

Top Self-reported Sport-related Activities Currently Played

Sport-related activity	*n* (Total = 53)	Percentage (Total = 68.8)
High-risk (*n* = 24; 47.17%)		
Ice Hockey	7	13.2
Rugby	4	7.6
Soccer	3	5.7
Wrestling	3	5.7
Lacrosse	2	3.8
Cheerleading	2	3.8
Other High-risk Sports	3	5.7
Low-risk (*n* = 29; 52.83%)		
Basketball	10	18.9
Volleyball	4	7.6
Rowing/Kayak	3	5.7
Swimming	3	5.7
Track and Field	2	3.8
Baseball	2	3.8
Curling	2	3.8
Other Low-risk Sports	3	9.4

Note: Other low-risk sports consisted of ultimate frisbee, fencing, and flag football. Other high-risk sports included gymnastics, power Olympic lifting, and martial arts/karate.

Participants had the option to report up to an additional three sports that they currently play (other than his/her identified primary sport). Twenty-seven individuals reported a second sport, 11 reported a third sport, and four reported a fourth sport. Frequencies and percentages for additional sports that individuals currently play by high- and low-risk athletes can be found in Table C1 in Appendix C.

Of the 32 individuals who self-reported a history of MHI, approximately 97% reported experiencing their most recent MHI at least three months prior – indicating that they were no longer within the 'acute' postinjury phase. Furthermore, the majority of participants (72%) were at least one year postinjury. Time since injury can be seen in Table 2. Moreover, the majority of individuals were between 16 to 20 years of age when they sustained their first MHI. Total ages ranged from infancy to 25 years of age. Ages at first MHI can be found in Table 3.

Table 2

Time since MHI

Most recent MHI (n = 32)		
Time since injury	n	Percentage
1 month	1	3.1
3 months	3	9.4
4-6 months	2	6.3
9-12 months	4	12.5
1-2 years	2	6.3
2-3 years	7	21.9
3-5 years	6	18.8
6 years or more	7	21.9

Table 3

Age at first MHI

Age at injury	High-risk MHI (n)	Low-risk MHI (n)	Non-athletic MHI (n)	Overall first MHI
0-5	0	0	1	1
6-10	0	0	2	2
11-15	3	1	3	7
16-20	15	2	1	18
21-25	3	0	1	4

Twenty-five individuals with a history of MHI reported experiencing symptoms longer than 20 minutes and 14 individuals acknowledged experiencing LOC. The majority of individuals who reported LOC stated that it lasted less than five minutes. Despite the fact that approximately 63% of individuals received medical treatment, only three were required to stay overnight in a medical facility. Furthermore, 12 individuals reported a history of more than one head injury (15.60% of all 77 participants; 37.50% of the 32 individuals with a history of MHI). All indicators of injury severity, including frequencies and percentages, can be found in Table 4.

Table 4

Indicators of Injury Severity of Self-reported MHI

Total *n* = 32	High-risk Athlete (*n* = 18)		Low-risk Athlete (*n* = 8)		Non-athlete (*n* = 6)	
Location of injury	*n*	% (of total)	*n*	%	*n*	%
Front of head	2	6.3	1	3.1	1	3.1
Right side of head	4	12.5	1	3.1	0	0
Left side of head	3	9.4	0	0	3	9.4
Back of head	6	18.8	5	15.6	2	6.3
Could not recall	3	9.4	1	3.1	0	0
Indicators of severity						
LOC	7	21.9	3	9.4	4	12.5
Duration of LOC						
Less than 5 minutes	4	12.5	2	6.3	3	9.4
Less than 30 minutes	2	6.3	1	3.1	1	3.1
Less than 24 hours	1	3.1	0	0	0	0
Self-reported concussion	5	46.9	6	18.8	3	9.4
Required stitches	1	3.1	1	3.1	1	3.1
Received medical treatment	1	37.5	5	15.6	3	9.4
Stayed overnight in medical facility	2	6.3	1	3.1	0	0

The majority (*n* = 24; 75%) of individuals sustained their MHI via a sport-related activity. Ice hockey was the most common sport-related etiology (41.67%); 23 (95.83%) were sustained at the competitive level. Etiologies of head injuries are presented Table 5. All 32 individuals with a history of MHI reported that they were not involved in any form of litigation related to their most recent injury (100.00%).

Table 5

Etiology of Self-reported MHI for Most Recent MHI

Total *n* = 32	High-risk Athlete (*n* = 18)		Low-risk Athlete (*n* = 8)		Non-athlete (*n* = 6)	
Etiologies	*n*	% (of total)	*n*	%	*n*	%
Sport-related activity	14	43.8	7	21.9	3	9.4
High-risk Sport	14	43.8	6	18.8	1	3.1
Ice Hockey	6	18.8	4	12.5	0	0
Rugby	3	9.4	0	0	0	0
Soccer	2	6.3	0	0	0	0
Other High-risk Sports	3	9.4	2	6.3	1	3.1
Low-risk Sport	0	0	1	3.1	2	6.3
Basketball	0	0	1	3.1	1	3.1
Baseball	0	0	0	0	1	3.1
Falling	2	6.3	0	0	0	0
Motor vehicle collision	1	3.1	0	0	1	3.1
Other	1	3.1	1	3.1	2	6.3

Note: Other high-risk sports included football, cheerleading, gymnastics, martial arts, snowboarding, and wrestling. The category of other included hitting head on furniture, running into a wall, and fights.

Twelve individuals sustained more than one MHI — all of which were sustained at least nine months prior and are described further in the results section. All reported that they were not involved in any form of litigation (100.00%). Refer to Table C2 for severity and etiology of injury information for participants' second reported MHI.

Eleven participants reported being diagnosed with a psychiatric condition (*M* age = 22.1, *SD* = 3.3; 14.3%), eight of whom were female (72.7%); five also reported a history of MHI (45.5%). In terms of athletic status, one individual was a high-risk athlete (9.1%), four individuals were low-risk athletes (36.4%), and six individuals were non-athletes (54.5%).

In terms of other demographic variables, most of the participants were right-handed (89.6%; one individual indicated that they are ambidextrous; 1.3%). A chi-square test of independence determined that education levels did not differ as a function of MHI status, χ^2 (5,76) = 4.553, *p* = .473, athletic status, χ^2 (16, 74) = 17.340, *p* = .364, or sex, χ^2 (5,76) = 7.174, *p* = .208. Additionally, faculty of study did not differ as a function of MHI status, χ^2 (8,76) = 5.576, *p* = .673, athletic status, χ^2 (16, 74) = 17.340, *p* = .364, or sex, χ^2 (8,76) = 10.917, *p* = .206. Similarly, ethnicity did not differ based on MHI status, χ^2 (7,77) = 6.776, *p* = .453, athletic status, χ^2 (14,75) = 13.498, *p* = .488, or sex, χ^2 (7,77) = 2.566, *p* = .922. Frequencies and percentages of education level, ethnicity, and faculty of study can be seen in Tables C3, C4, and C5.

Post-season testing session

Sixty-four participants (83.12%; *M* age = 21.21, *SD* = 2.78) returned for the post-season testing session. Of those who did not return (*M* age = 20.23, *SD* = 2.52), 53.8% were male, and 30.8% were non-athletes (one had a prior history of MHI), 30.8% were low-risk athletes (zero reported a history of MHI), and 38.5% were high-risk athletes (four had a history of MHI). Of those who did return, 23 were male (35.94%) and 26 were from the MHI group (40.63%). In terms of athletic status, 20 of the individuals who returned were non-athletes (31.3%; five had a history of MHI), 25 were low-risk athletes (39.0%; eight reported a prior history of MHI), and 19 were high-risk athletes (29.7%; 14 reported a prior history of MHI)[1]. Moreover, of the 44 athletes who returned, 16 were recreational athletes (36.4%) and 28 were competitive athletes (63.6%). Since the first

[1] There was a similar distribution based on athletic status in the original sample — 31.2% were non-athletes, 37.7% were low-risk athletes, and 31.2% were high-risk athletes.

testing session, one participant indicated that they had been diagnosed with a psychiatric condition (1.56%).

Notably, three individuals (4.7%) sustained a MHI during a sport-related activity (i.e., hockey, basketball, gymnastics) between the pre- and post-testing sessions (*M* age= 20.33, *SD*= .58); all were all high-risk athletes all had reported at least one prior MHI in the pre-season testing session, and all reported experiencing their symptoms for more than 20 minutes; one reported having a LOC for less than five minutes. One of these three individuals actually reported sustaining two MHIs between the pre- and post-season testing sessions. He was a 20-year-old male who had also reported having sustained seven MHIs prior to the pre-testing session. For this second event, he reported striking the front of his head while playing ice hockey one-month prior and experienced symptoms for more than 20 minutes with a LOC for less than five minutes. No overnight stay in a medical facility was needed, however the participant received medical treatment. The injury did not result in any form of litigation.

All indicators of injury severity are provided in Table 6. None of the individuals were involved in litigation due to their injuries.

Table 6

Indicators of Injury Severity of Self-reported MHI Sustained Between Pre- and Post-season Testing Sessions

Indicators of Severity	MHI (*n* = 3)	
Location of injury	*n*	Percentage
Front of head	1	33.33
Left side of head	2	66.67
Indicators of severity		
Symptoms 20+ minutes	3	100.00
LOC	1	33.33
Self-reported concussion	3	100.00
Received medical treatment	2	66.67
Stayed overnight in medical facility	3	100.00

Materials

Materials consisted of various self-report questionnaires, standardized/protected neuropsychological measures, and non-invasive physiological measures. All questionnaires are attached in Appendix A.

Physiological Measures

Individuals' pulse, EDA, and respiration were measured using Polygraph Professional Suite Software and Polygraph Professional equipment (Limestone Technologies, 2008). The Datapac USB 16-bit Data Acquisition Instrument was used along with a 16-inch Acer Laptop Computer to measure EDA, pulse, and respiration rate. Specifically, silver-silver chloride pads were used to measure EDA, and were placed on the index and fourth fingers on the participant's non-dominant hand. A pulse oximeter was placed on the middle finger of the participant's non-dominant hand to measure pulse. Respiration was recorded via two pneumatic chest bands—one was placed around the abdomen, the other around the chest. To measure BP, an automatic blood pressure monitor (model: HEM-711DLXCAN) was placed on the participant's non-dominant forearm to measure BP (Omaron Healthcare Inc.). Further, saliva samples were collected using five mL glass saliva tubes as part of a greater study (though not analyzed for the purposes of the current study).

Neuropsychological Measures

All neuropsychological assessment measures were paper and pencil tests and were administered by one of six trained assessors.

The Letter-Number Sequencing (WAIS-III, Wechsler, 1997) was administered to measure working memory, cognitive flexibility, and sequencing. The participant is read aloud a list of letters and numbers, and is instructed to repeat back the numbers followed by the letters in alphabetical/chronological order. Two versions were administered – Version I during pre-season testing, and Version II during post-season testing (in order to minimize practice effects). In the post-season session, participants were asked to repeat first the letters that were read aloud, followed by the numbers. See Wechsler (1997) for validity and reliability indices (e.g., range .70 - .79).

The Symbol Digit Modalities Test (SDMT; Smith, 1982) primarily measures working memory and processing speed. In this test, the examinee is given 90 seconds to substitute as many numbers for randomized geometric figures according to a re-coding template. See Smith (1982) for validity and reliability indices (e.g., range from .69 - .88).

The Trail Making Test (TMT; Delis, Kaplan, & Kramer, 2001) primarily measures visual search, scanning, processing speed, and mental flexibility. Various letters and numbers are randomly distributed across a page. For the pre-testing session, Part II of the TMT was administered. Participants were asked to connect numbers as quickly as possible in ascending order, followed by, a second task during with the participant was asked to alternate between connecting numbers in ascending order and letters in alphabetical order. In order to minimize practice effects, for the post-testing session, Part III of the TMT was administered. Participants were asked to connect letters in alphabetical order, followed by alternating between letters and numbers. Indices of reliability and validity are provided in the controlled publication tool for Delis-Kaplan Executive Function System (see References - Cronbach's alpha range from $\alpha = .59$ to $\alpha = .86$).

The Wide Range Achievement Test-IV (WRAT-IV; Wilkinson & Robertson, 2006) was administered during pre-season testing only in order to obtain a proxy of intellectual capacity. Tests of reading and spelling were included. In the word reading task, participants were asked to read aloud a list of words. In the spelling condition, the participants were asked to spell words that were read to them by the examiner. Accuracy and response times were recorded. The WRAT-IV was not re-administered during post-season since it has been demonstrated that intellectual capacity is rarely affected by a MHI. Refer to Wilkinson and Robertson (2006) for indices of reliability and validity - Cronbach's alpha range from $\alpha = .74$ to $\alpha = .91$.

Self-report Questionnaires

Demographics (Part I) and Post-Concussion Symptom Scale (*PCS;* Gouvier, Cubic, Jones, Brantley, & Cutlip, 1992). The Everyday Living Demographic Questionnaire (ELQ; Brock University, Neuropsychology Cognitive Research Laboratory, 2008) was administered to collect information including age, sex, medical history, history of MHI, education, sleep habits, recreational/athletic history, and other demographic information. Many questions were also added for the purposes of distraction from the primary purpose of the study. In addition, other questions were included to maintain demographic comparisons to others studies conducted in the Neuropsychology Cognitive Research Lab at Brock University. Importantly, the questions pertaining to MHI status were among many other questions pertaining to medical history. The question that specifically relates to MHI status states, “Have you ever sustained an injury to your head with a force sufficient to alter your consciousness (e.g., dizziness, vomiting, seeing stars, or loss of consciousness, or confusion)?”. A composite variable for MHI severity was created with self-reported information pertaining to the injury[2]. Attached to the ELQ was a modified version of the PCS — an established 10-item scale that assesses self-reported symptoms. The individual is asked to rate the frequency, (from one [not at all] to five [all the time]), intensity (from one [not at all] to five [crippling]), and duration (from one [not at all] to five [constant]) for each symptom listed.

Demographics (Part II) and Post-Concussion Symptom Scale. A modified version of the previously described Everyday Living Demographic Questionnaire (ELQ-II) was administered at the post-season testing sessions. Questions emphasizing any changes the individual may have experienced since the first session (e.g., head injury, PCS) were

[2] The injury severity variable was calculated with the following self-reported symptoms: previous MHI [no = 0, yes = 1], symptoms lasting more than 20 minutes [no = 0, yes = 1], loss of consciousness [no = 0, yes = 1], duration of LOC [less than 5 minutes = 1, less than 30 minutes = 2, less than 24 hours = 3, less than 1 week = 4, less than 1 month = 5, greater than 1 month = 6], whether the injury resulted in concussion [no = 0, yes = 1], if stitches were required [no = 0, yes = 1], if the he/she received medical treatment [no = 0, yes = 1], if he/she was admitted to the hospital occurred [no = 0, yes = 1], and whether he/she sustained multiple head injuries [no = 0, yes = 1]. Scores were tallied and ranged from 0 to 14.

included. Robust information, including sex, age, education, and other questions, were not reassessed.

*UPPS-P Impulsive Behaviour Scale (*UPPS-P*;* Whiteside & Lynam, 2001) was used as a measure of impulsive behaviour and includes five constructs: negative urgency (NU), (lack of) premeditation (PM), (lack of) perseverance (PV), sensation seeking (SS), and positive urgency (PU). It is rated using a Likert scale that ranges from one (agree strongly) to four (disagree strongly). Examples from each of the subscales include: NU – "I have trouble controlling my impulses"; PM – "I have a reserved and cautious attitude towards life"; PV – "I generally like to see things through to the end"; SS – "I generally seek new and exciting experiences and sensations"; PU – "When I am in a great mood, I tend to get into situations that could cause me problems". Reliabilities (Cronbach's alpha) range from $\alpha = .84$ to $\alpha = .92$ (Whiteside & Lynam, 2001).

*Buss & Perry Aggression Questionnaire (*BPAQ*;* Buss & Perry, 1992) is a 29-item scale that measures aggression. The participant uses a five-point scale from one (extremely uncharacteristic of me) to five (extremely characteristic of me) to rate how well each statement characterizes him/her. The questionnaire consists of four subscales: hostility (H), anger (A), verbal aggression (VA), and physical aggression (PA). An example of each includes: H – "I am sometimes eaten up with jealousy"; A – "When frustrated, I let my irritation show"; VA – "I often find myself disagreeing with people"; PA – "Once in a while, I can't control the urge to strike another person". Note that PA is also a reflection of reactive aggression. Psychometric properties are in the acceptable range (Cronbach's alpha, $\alpha = .80$; see Buss & Perry, 1992).

Modified Competitiveness Questionnaire (MC) was a modification of two questionnaires: the *Sport Orientation Questionnaire (*SOQ*;* Gill & Deeter, 1988) and the Revised Competitiveness Index (CI-R; Houston, Harris, McIntire, & Francis, 2002). This modified version consisted of two of the three subscales of the SOQ (i.e., 12 of its 25 items) and all 14 statements from the CI-R. (Due to the overlap in competitiveness statements on the two scales, and the emphasis solely on sports in the SOQ, 13 items of the SOQ were omitted). The SOQ is a 25-item measure that assesses achievement motivation and competitiveness in sport. It has three subscales, including win orientation (WO), goal orientation (GO), and competitiveness (C), the first two of which were used in this study. Participants are asked to rate each statement as it applies to them on a scale from one (strongly disagree) to five (strongly agree). An example for each includes: WO – "The only time I am satisfied is when I win"; GO – "I am most competitive when I try to achieve personal goals". The *Revised Competitiveness Index (CI-R;* Houston et al., 2002) provided a measure of competitiveness and included statements such as: to rate statements such as – "I get satisfaction from competing with others". Reliabilities (Cronbach's alpha) for each questionnaire are acceptable (Sport Orientation Questionnaire: ranged from $\alpha = .73$ to $\alpha = .94$; see Gill & Deeter, 1988; Competitiveness Index-Revised: $\alpha = .90$; see Houston et al., 2002).

Procedure

Participants were tested in one of three time-slots (10:30 a.m., 1:00 p.m., or 3:30 p.m. – these timings were maintained during post-season testing) and by one of six examiners. Examiners were trained by the primary investigator, who was also one of the examiners. Note that there was no statistical variation in participant performance across the examiners as assessed post-data collection. Examiners followed a strict and practiced protocol, including a verbal script and standardized instructions for the neuropsychological measures. Testing was individualized, and sessions ranged from one hour and 30 minutes to two hours in length. Prior to arrival on the day of the study, participants provided a 3 mL saliva sample upon awakening and a 3 mL sample 45 minutes after waking. Prior to this, participants were provided specific instructions on how to procure their samples. All were collected as part of a larger study investigating supplementary and contributing factors of MHI, and will not be reported in this thesis. Upon arrival, participants were introduced to the study, provided consent, and asked if they had any questions. All were reminded of their right to withdraw from the study, confidentiality and anonymity procedures, and compensation that they were eligible to receive. Participants chose to receive either research participation credit or the gift card.

Participants began the testing session by being asked to rate their current state of arousal on a scale from one to 10 (i.e., “On a scale from one to 10, with one being very relaxed and 10 being very stressed, how are you feeling at the moment?”). They were then invited to assist the researcher with connecting the physiological equipment, namely a pulse oximeter, pneumatic chest bands, and silver-silver chloride plated pads. A 3-minute baseline measure of EDA, HR, and respiration was then recorded. Afterwards, the participant removed the abovementioned physiological equipment and aided the examiner in attaching a blood pressure cuff to their non-dominant forearm. Blood pressure was assessed by the automatic monitor and the cuff removed. The participant then provided another 3 mL saliva sample.

Next, the researcher administered the neuropsychological measures in the following order: SDMT, LNS, TMT, and the WRAT-IV. The test order for all subjects remained static to hold constant fatigue and ‘carry over’ effects. Upon completion, another 3 mL saliva sample was obtained.

Finally, participants were given the questionnaires to complete which were also presented in a constant order, namely, the UPPS-P, BPAQ, MC, and the ELQ. Additional questionnaires were administered as part of a larger study and will not be discussed further.

At the end of the pre-season season testing session, participants were given an ‘interim’ debriefing — in this case, they were not provided with full intention of the study (i.e., MHI), but were given a general description of the testing purpose, and an invitation to return, as well as relevant contact information in the event they had any questions or issues of clarification. Participants were thanked for their time, given appropriate compensation, and reminded that they would be contacted in approximately three months time to return for a similar testing session.

The procedure was similar for the post-season testing session with the following exception: version II of the LNS and part III of the TMT were administered (to control for practice effects) and the WRAT-IV was not re-administered. As before, some measures were gathered as part of a larger study, and are not reported here. At the end of the testing session, participants were thanked for their time, debriefed, and compensated accordingly. During the debriefing, participants were informed as to the actual nature of the study, including the fact that head injury status was a variable of interest. Participants were given information pertaining to head injuries, counseling services, and the primary researchers' contact information.

Results

Data Analyses

Analyses were conducted using the Statistical Package for the Social Sciences (SPSS; Version 22, 2014). All assumptions have been examined and can be assumed to have been met unless otherwise stated. All eta-squared values were calculated manually. For all but one analysis, sex was not found to influence the results. Thus, unless otherwise stated, results are presented without sex as a covariate. The analyses were also conducted with and without individuals who reported being diagnosed with a psychiatric condition, as it has been found that psychiatric conditions can be associated with personality (e.g., Alt, 1999; Starcevic, Uhlenhuth, Fallon, & Pathak, 1996), neurocognitive function (e.g., Bloemsma et al., 2013; Zakzanis, Leach, & Kaplan, 1998), and physiological arousal (Dienstbier, 1989; Fisher, Granger, & Newman, 2010). Analyses are reported without excluding individuals with a diagnosed psychiatric condition, unless the exclusion of such individuals significantly affected results. For post-hoc tests, when the Tukey's HSD test was performed with unequal sample sizes, the Tukey-Kramer approach was used. Pearson Chi-square tests of independence were used to examine group categorical differences. Analysis of Variance (ANOVA) and *t*-test statistics were used to examine mean differences between MHI and no-MHI groups and non-athletes, low-risk athletes, and high-risk athletes. Multiple regressions were conducted to predict various outcomes from MHI status, athletic status, and various personality, physiological, and cognitive variables. Tables can be found in text or in Appendix C.

Time of Day and Tester Effects

Pearson Chi-square tests of independence revealed that the time of day when participants were tested did not differ as a function of MHI status, athletic status, or sex (see Table C6). Likewise, there were no tester effects for MHI status, athletic status, or sex (see Table C7).

Health and Psychosocial Demographic Information

Chi-square tests of independence determined that there were no differences for MHI status, athletic status, and sex for any of the health variables assessed (i.e., hospitalizations, diagnosed psychiatric condition, diagnosed learning disorder, medication use, use of any extra assistance, including physiotherapy, occupational therapy, learning resource teacher, or educational assistant). Furthermore, there were no differences between groups relating to enjoyment of academics or in the number of courses participants were currently enrolled in. See Tables C8 to C19.

Demographic variables relating to substance use were also examined. There were no differences based on MHI status, athletic status, and sex for cigarette smoking and drinks consumed per outing or per week (see Tables C20-C22). However, Chi-square analyses revealed that MHI and athletic groups differed in terms of recreational drug use, χ^2 ($df = 2$) = 13.575, $p = .001$, such that both non-athletes without a history of MHI and high-risk athletes with a history of MHI were more likely to use recreational drugs (see Table C23). Athletic and MHI groups also differed by whether they regularly consumed alcohol, χ^2 ($df = 2$) = 13.173, $p = .001$; this was particularly the case for high-risk athletes with a history of MHI (see Table C24). There were no differences based on sex for consumption-related variables, except drinks consumed per outing approached significance for sex, such that males consumed more alcohol per outing (see Tables C25-C27).

Finally, there were no differences in the individual's sleep ratings (see Table C28), their current alertness (see Table C29), their enjoyment of life (see Table C30), or their number of life stressors (see Table C31). However, a 2 (MHI status) by 3 (athletic status) ANOVA revealed that there was a difference for self-reported day-to-day stress, such that individuals with a history of MHI ($M = 6.087$, $SD = .363$) reported significantly more daily stress than individuals with none ($M = 4.997$, $SD = .314$); there was no interaction or any differences based on athletic status (see Table C32). Similarly, there was no difference for sex and MHI status based on sleep ratings (see Table C33), though there was a significant difference for self-reported current alertness, such that males reported being more alert than females at the time of testing (see Table C34). There were also no differences based on enjoyment of life and total life stressors for MHI and sex (see Tables C35 and C36), though again, only MHI groups (and not sex) significantly differed based on daily stress (see Table C37).

Post-concussive Symptoms

Symptoms associated with concussion as a function of MHI status were examined via a one-way ANOVA. Total PCS ratings approached significance, $F(1, 74) = 3.878$, $p = .053$, $\eta^2 = .052$, such that persons with MHI reported a greater frequency of PCS than persons without MHI. Additionally, one-way ANOVAs indicated that individuals with a previous MHI endorsed significantly higher scores (i.e., total endorsement for a symptom including its frequency, duration, and intensity) for specific symptoms of headache, $F(1, 72) = 4.004$, $p = .049$, irritability, $F(1, 74) = 5.739$, $p = .019$, and anxiety, $F(1, 74) = 4.307$, $p = .041$, compared to individuals without a previous MHI. There were no significant differences based on MHI status for: dizziness, memory problems, difficulty concentrating, fatigue, visual disturbance, aggravated by noise, judgment problems, or overall PCS score– however means were in the expected direction. Refer to Tables C38 to C52 for all ANOVAs and descriptive statistics.

Hypothesis 1: High-risk Sports Associated with More MHIs

As expected, high-risk sports were associated with more MHIs, as revealed by a Chi-square test of independence, $X^2(2) = 18.081$, $p<.001$. Frequencies of athletic status by MHI status can be seen in Table 7.

Table 7

Frequencies of Participants by MHI and Athletic Status

Athletic Status	*No MHI (Percentage)*		*MHI (Percentage)*		*Total (Percentage)*	
Non-athlete	18	(23.4%)	6	(7.8%)	24	(31.2%)
Low-risk Athlete	21	(27.2%)	8	(10.4%)	28	(36.4%)
High-risk Athlete	6	(7.8%)	18	(23.4%)	24	(31.2%)
Total	45	(58.4%)	32	(41.6%)		

In conjunction with aforementioned analyses, a one-way ANOVA found that the athletic groups significantly differed in the number of reported MHIs, $F(2, 74) = 5.678$, $p = .005$ (see Table C53). A post hoc analysis (Tukey's HSD test) revealed that high-risk athletes ($M = 1.800$, $SD = 2.415$) sustained significantly more MHIs than low-risk athletes (M = .393, SD = .796), p = .007, and non-athletes (M = .583, SD = 1.283), p = .028. The number of MHIs sustained did not differ between non-athletes and low-risk athletes. Frequencies of MHIs sustained by athletic status can be found in Table 8.

Table 8

Frequencies of MHIs by Athletic Status

Number of MHIs	*High-risk Athlete* *n = 24*	*Low-risk Athlete* *n = 29*	*Non-athlete* *n = 24*
None	6	21	18
One	13	4	3
Two	1	2	0
Three	1	1	2
Four	0	1	0
Five	0	0	1
Seven	2	0	0
Nine	1	0	0

Hypothesis 2: Individuals with MHI will Experience Cognitive Challenges

The hypothesis that individuals with a history of MHI will experience cognitive challenges, as indicated by the SMDT, LNS, and TMT, (i.e., slower processing speed, impaired working memory, cognitive, and attention) compared to their non-injured cohort was not supported[3]. Intellectual capacity also did not greatly differ between the groups. However, participants with a history of MHI performed significantly faster on the Word Reading subtest total time than the participants without a history of MHI, $F(1,69)$ = 5.264, p = .025 (perhaps indicating a preinjury cognitive resilience in university students

[3] The assumption of normality was violated for TMT-II and TMT-IV errors and for the TMT-IV total time. The assumption of homogeneity of variance was also violated for TMT-II total errors. However, the data were not transformed; analyses were performed with and without outliers and there were no differences in the aforementioned neuropsychological measures.

who have MHI that is neuroprotective in some fashion – see Stern, 2009). There were no differences based on athletic status for any neurocognitive or intellectual capacity measures. Refer to Tables C54 to C60 for all analyses and descriptive statistics.

Hypothesis 3: Increased Risky Personality Traits for Individuals With a History of MHI and High-risk Athletes

To investigate whether individuals with MHI, particularly in high-risk sports, were more prone to have risky personality traits various ANOVAs and hierarchical multiple regressions were performed. The particular personality traits investigated were impulsivity (via the UPPS-P Impulsive Behaviour Scale), aggression (via the Buss and Perry Aggression Questionnaire), and competitiveness (via the Modified Competitiveness Questionnaire). For the trait of impulsivity and its subscales (i.e., negative urgency, premeditation, perseverance, sensation seeking, and positive urgency) 2 by 3 ANOVAs revealed that there were no significant main effects of MHI status, athletic status, or the interaction term (see Tables C61to C72 for inferential and descriptive statistics). Similarly, there were no differences for the personality trait of aggression or any of its subscales (i.e., hostility, anger, verbal aggression, and physical aggression). See Tables C73 to C83 for inferential and descriptive statistics. However, when individuals with a reported psychiatric condition were excluded from analyses, there was a significant main effect of MHI for endorsed levels of sensation seeking, and a trend for physical aggression, such that individuals with a history of MHI endorsed higher levels of both sensation seeking and physical aggression (see Tables C84-87).

Lastly, a 2 (MHI status) by 3 (athletic status) ANOVA revealed that for competitiveness, there was a trend for MHI status, $F(1,71) = 3.106$, $p = .082$, $\eta^2 = .033$, such that individuals with a previous MHI endorsed higher levels of competitiveness than individuals without a previous MHI. Likewise, there was a significant main effect of athletic status, $F(2,71) = 4.531$, $p = .014$, $\eta^2 = .095$, such that both athlete groups endorsed elevated competitiveness compared to non-athletes. See Figure 1 and Table C88 for means and standard deviations.

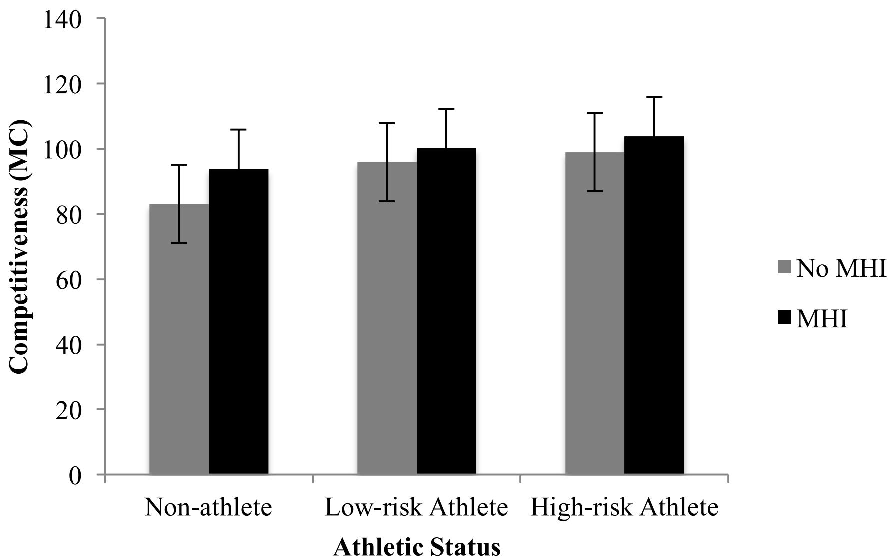


Figure 1. Levels of Endorsed Competitiveness for Individuals with and without a History of MHI and High-risk, Low-risk, and Non-athletes.

For exploratory purposes, MHI and athletic status variables were considered independently. Specifically for MHI status, a one-way ANOVA revealed a trend for individuals with a history of MHI to endorse higher levels of sensation seeking than individuals without MHI, $F(1,74) = 3.419$, $p = .068$, $\eta^2 = .044$ (see Figure 2). See Tables C89 to C94. When individuals with a psychiatric condition were excluded from the analyses, levels of endorsed sensation seeking differed significantly between individuals with and without a history of MHI, $F(1,63) = 5.809$, $p = .019$, $\eta^2 = .084$. See Tables C95 to C101.

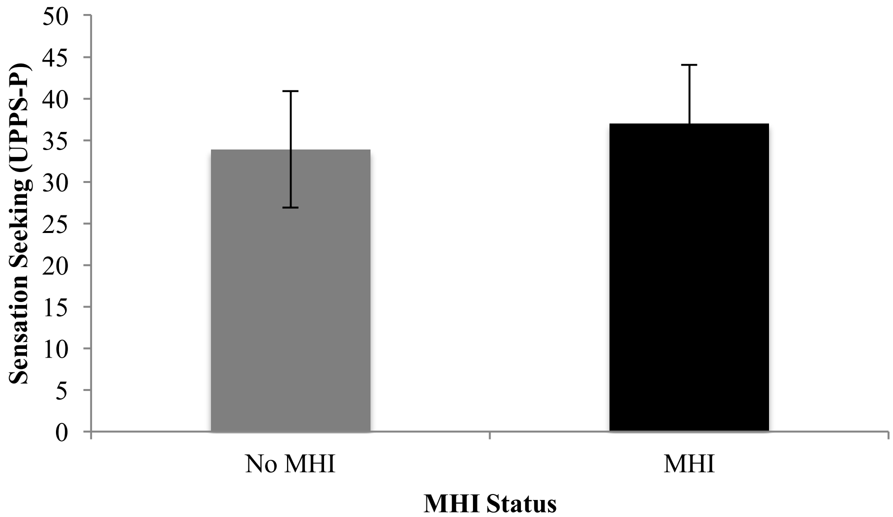


Figure 2. Levels of Endorsed Sensation Seeking for Individuals with and without a History of MHI.

For trait levels of aggression, there were no differences between individuals with and without a previous MHI on any subscales related to aggression, except physical aggression. Individuals with a history of MHI endorsed significantly higher levels of physical aggression than individuals without MHI, $F(1,74) = 4.085$, $p = .047$, $\eta^2 = .052$ (see Figure 3). Refer to Tables C102 to C107.

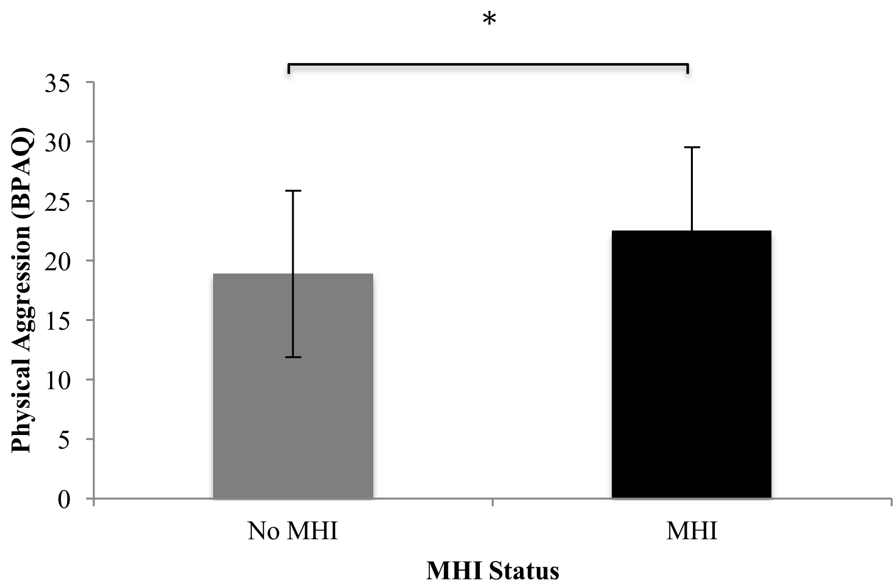


Figure 3. Levels of Endorsed Physical Aggression for Individuals with and without a History of MHI.

For levels of competitiveness, it was found that individuals with a history of MHI (M = 100.906, SD = 13.994) endorsed significantly higher levels of competitiveness (total MC score) than individuals without a history of MHI (M = 91.200, SD = 14.347), $F(1,75) = 8.735$, $p = .004$, $\eta^2 = .090$ (see Figure 4 and Table C108).

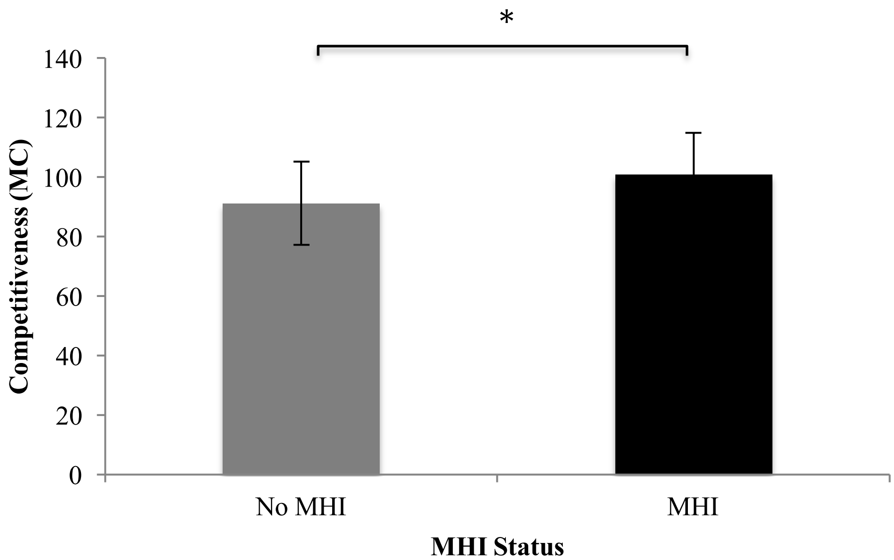


Figure 4. Levels of Endorsed Competitiveness Total Score for Individuals with and without a History of MHI.

When analyses were conducted for athletic status, high-risk, low-risk, and non-athletes did not differ on levels of endorsed impulsivity or any associated subscales. However, there was a trend for endorsed levels of sensation seeking, $F(2,73) = 3.050$, $p = .053$, $\eta^2 = .077$. Tukey's HSD post-hoc analyses were examined, and there was a trend for high-risk athletes to endorse higher levels of sensation seeking compared to non-athletes, $p = .065$, though there were no differences between the two athletic groups (low- and high-risk athletes), $p = .921$. There were no differences for aggression or any of the associated subscales. Lastly, there was a significant difference for levels of endorsed competitiveness, $F(2,74) = 10.044$, $p < .001$, $\eta^2 = .214$. Post hoc analyses (Tukey's HSD) revealed that non-athletes ($M = 85.750$, $SD = 14.543$) endorsed significantly lower levels of competitiveness compared to low-risk athletes ($M = 96.714$, $SD = 9.480$), $p = .012$, and high-risk athletes ($M = 102.680$, $SD = 15.790$), $p = .012$. There were no significant differences between low- and high-risk athletes, $p = .244$ (see Figure 5). Refer to Tables C109 to C121.

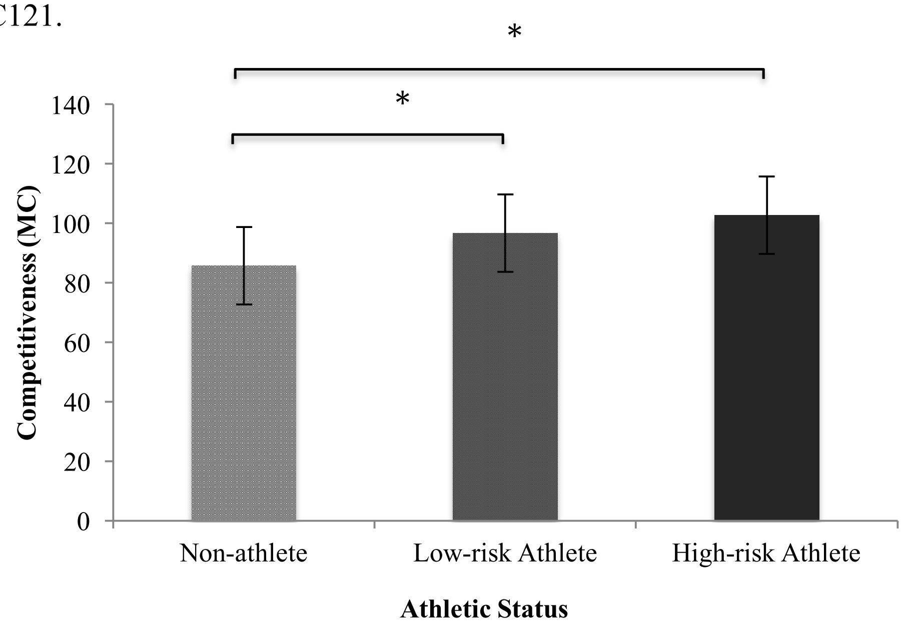


Figure 5. Levels of Endorsed Competitiveness for Non-athletes, Low-risk Athletes, and High-risk Athletes.

Risky Personality will be Associated with More MHIs

Various hierarchical multiple linear regressions were performed to examine whether individuals who endorse elevated levels of impulsivity, aggression, and competitiveness will have sustained more MHIs, regardless of athletic status. For each analysis, athletic status was entered on the first step and the personality trait of interest was entered on the second step, predicting the number of MHIs sustained. The only personality trait that significantly predicted the number of MHIs over and above athletic status was aggression, $F(2,72) = 6.306$, $p = .004$. Refer to Tables C122 to C124.

Hypothesis 4: Decreased Physiological Arousal for Individuals with a History of MHI

To examine whether individuals with a history of MHI have decreased physiological arousal compared to those without a history of MHI, one-way ANOVAs were conducted. Respiration rate was measured in cycles per minute (CPM). Pulse was measured in terms of averaged amplitude and CPM. Heart rate variability was measured by taking the SD of the time between heartbeats. The SD of eight beat-to-beat intervals was analyzed; only beats that had an associated respiration rate of .15 to 4.0 Hz were examined (see Kurths, Voss, Saparin, Witt, Kleiner, & Wessell, 1995 for review). Electrodermal activation was measured in terms of averaged amplitude. Due to an error in data collection, two participants' physiological data could not be analyzed.

There were no significant differences in individuals' self-report of subjective arousal between the MHI and no-MHI groups. Furthermore, there were no differences between the groups for the measures of pulse (including HR variability), respiration, or BP.[4] Also, sex was found to be a significant covariate for systolic BP, $F(1,74) = 15.358$, $p < .001$. Refer to Tables C125 to C135.

For EDA amplitude, a 2 (MHI status) by 3 (athletic status) ANOVA revealed that there was a trend for the main effect of MHI, $F(1,70) = 3.134$, $p = .081$; the main effect of athletic status and the interaction between MHI and athletic status were not significant (see Tables C136 and C137). Further analyses determined that individuals with a history of MHI ($M = .947$, $SD = .871$) displayed significantly decreased EDA amplitude compared to individuals without a history of MHI ($M = 1.850$, $SD = 1.887$), $F(1,74) = 6.170$, $p = .015$, $\eta^2 = .07$ (see Figure 6). Analyses were also conducted with the MHI group divided into LOC and no LOC; overall, there was a significant difference in EDA amplitude between the groups, $F(2,73)= 3.463$, $p= .037$. Fisher's least significant

[4] Pulse CPM was conducted without two identified outliers as it violated the assumption of normality and results differed quite drastically. There remained no significant differences between the groups.

difference (LSD) post-hoc test demonstrated that MHI with LOC, $p = .043$, and MHI no LOC, $p = .037$, both significantly differed from the no MHI group, though not from one another.

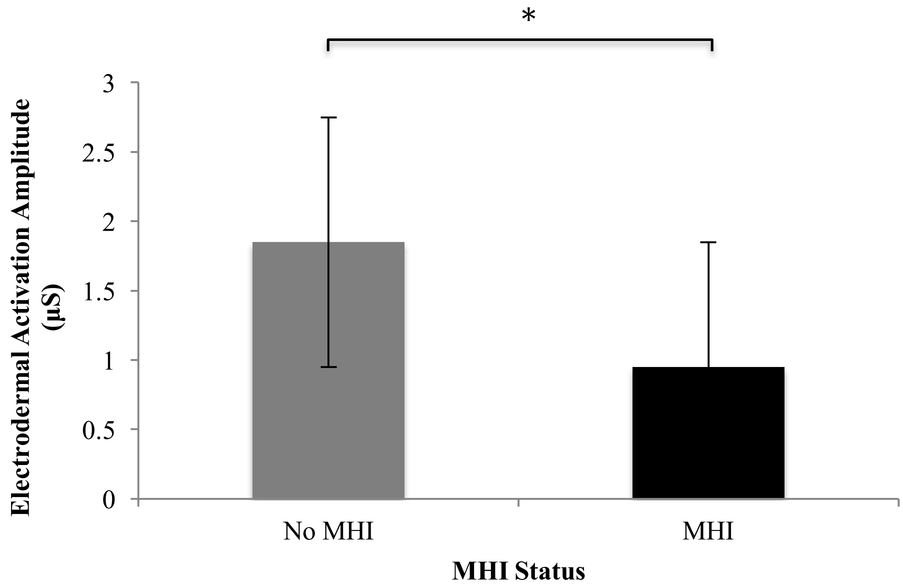


Figure 6. EDA Amplitude for Individuals with and without a History of MHI.

Subsequent analyses were performed for EDA across the 3-minute time interval in which physiological activity was measured by each minute. A 2 (MHI status) by 3 (time interval) repeated measures ANOVA demonstrated that individuals with a history of MHI demonstrated significantly decreased EDA amplitude compared to individuals without a history of MHI across the three minute interval, $F(1,71) = 4.450$, $p = .038$ (see Figure 7 and Tables C138 and C139).

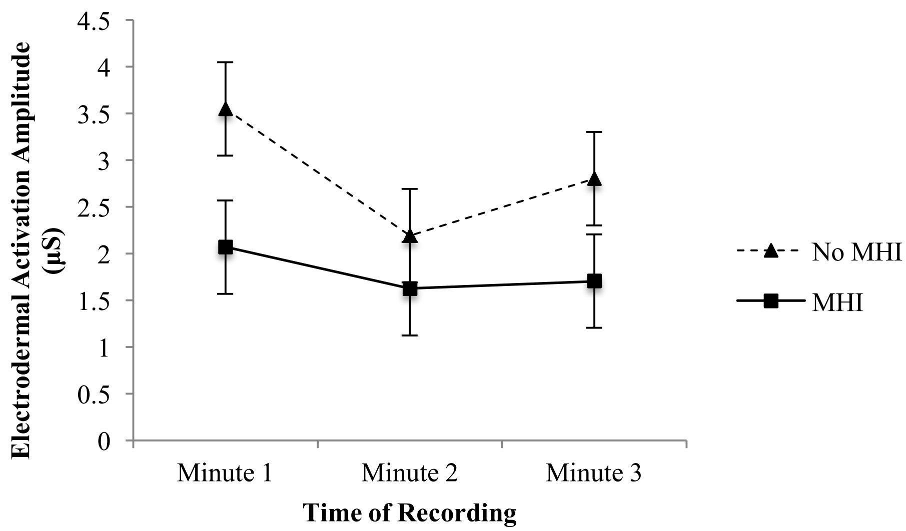


Figure 7. EDA Amplitude over a Three-Minute Recording for Individuals with and without a History of MHI.

In terms of physiological differences based on athletic status, pulse CPM significantly differed amongst the groups, $F(2,74) = 5.550$, $p = .006$. Post hoc comparisons using the Tukey's HSD test indicated non-athletes ($M = 77.516$, $SD = 13.252$) produced significantly higher pulse CPM than high-risk athletes ($M = 65.857$, $SD = 6.390$; $p = .004$). Low-risk athletes did not significantly differ from either group ($M = 72.518$, $SD = 14.537$). There were no other differences in physiological arousal based on athletic status.

Hypothesis 5: Risky Personality Traits will be Associated with Lower Physiological Arousal, but MHI Status will Predict Physiological Arousal Over and Above Personality

The fifth hypothesis was partially supported. To address this hypothesis, multiple hierarchical regressions were conducted; the personality trait of interest was entered on the first step, athletic status was entered on step two, and MHI status was entered on the last step with physiological arousal as the dependent variable. Electrodermal activation amplitude was used as the variable to represent physiological arousal as it has been found to be a sensitive proxy of autonomic nervous system (ANS) functioning (e.g., see Fowles, 1974; Lazarus et al., 1963). For the overall trait of impulsivity, neither impulsivity nor athletic status predicted EDA; however, MHI status did, over and above the other variables. The same was found for four of the five impulsivity subscales of negative urgency, premeditation, perseverance, and positive urgency. The subscale of sensation seeking significantly predicted EDA on the first step, while on the final step MHI approached significance, predicting EDA over and above sensation seeking and athletic status, p = .054. Interestingly, the overall model also significantly predicted EDA, $F(3,71) = 3.026$, p = .035. Refer to Tables C140 to C145. See Figure 8 for the relationship between sensation seeking and EDA by severity of MHI (no MHI, MHI without LOC, and MHI with LOC).

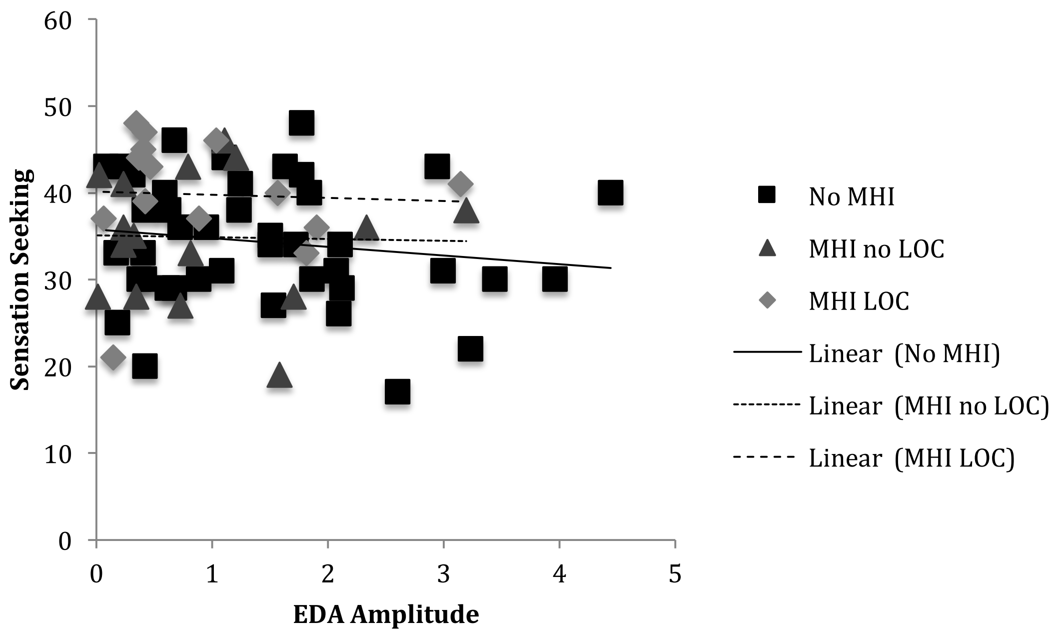


Figure 8. Sensation Seeking and EDA by Injury Severity.

Separate hierarchical multiple regressions were also performed on the aggression-related variables. Overall aggression and the subscales of physical aggression and verbal aggression significantly predicted EDA amplitude, while MHI status approached significance on the final step. The overall models for aggression, $F(3,69) = 3.095$, $p = .032$, physical aggression, $F(3, 71) = 3.688$, $p = .016$ (see Figure 9), and verbal aggression, $F(3,71) = 3.110$, $p = .032$ were also significant.

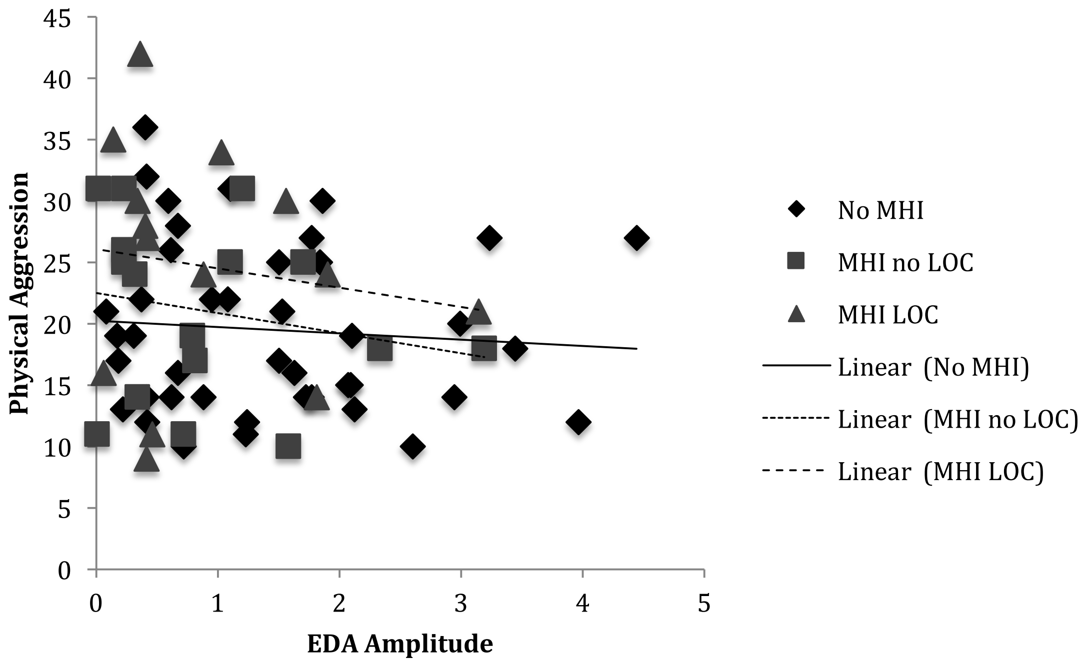


Figure 9. Physical Aggression and EDA by Injury Severity.

For the subscale of anger, MHI predicted EDA amplitude over and above anger and athletic status — neither of which predicted EDA; and although the subscale of hostility significantly predicted EDA, MHI significantly predicted EDA over and above hostility and athletic status. The overall model was also significant, $F(3,72) = 4.151$, $p = .009$. Refer to Tables C146 to C150. Finally, for the trait of competitiveness, neither competitiveness nor athletic status predicted EDA, while MHI predicted EDA over and above competitive and athletic status. Refer to Table C151.

Hypothesis 6: Pre-season Personality will Predict Post-season Outcomes, though MHI will Predict Outcome Over and Above Pre-season Status

Contrary to expectations, only three individuals sustained a MHI between the pre- and post-season testing sessions, all of whom had already sustained at least one self-reported MHI prior to testing. Thus, analyses for this hypothesis are limited and no definite conclusions can be made.

Nonetheless, multiple regression analyses were conducted with various post-season outcomes as dependent variables and pre-season scores and MHI status as predictor variables. Firstly, a hierarchical multiple regression found that the pre-season SDMT score significantly predicted the post-season score; however, MHI status predicted the post-score over and above the pre-score, $F(1,61) = 59.805$, $p < .001$ (see Table C152). Further, when the three individuals who sustained a MHI during the season were excluded from analyses, the unique variance in the SDMT total score accounted for by MHI decreased (from $sr^2 = .023$ to $sr^2 = .019$). For the other neuropsychological measures, while the pre-season score predicted the post-season score, MHI status did not predict the post-season score over and above the pre-season score (see Tables C152-C155). Similarly, separate hierarchical multiple regressions were conducted with the personality variables of interest (i.e., impulsivity, aggression, and competitiveness) and the pre-season score predicted the post-season score in all cases; however, MHI status did not predict the post-season score over and above the pre-season score (see Tables C156-C159).

Discussion

The purpose of the current study was to investigate whether there are particular premorbid factors (i.e., personality characteristics) that contribute to the outcome observed post-MHI. It was also examined if the sequelae observed post-MHI are similar to the cognitive, physiological, and behavioural sequelae observed post-moderate to severe TBI. In a two-part design (designed to mimic a typical athletic season), physiological arousal, cognitive abilities, and personality traits were examined in a group of university students.

It is important to note that all demographic information, including MHI status and medical history, was collected via self-report. This is contrary to other studies that have collected MHI information using other methods, such as medical reports or observations from medical personnel (e.g., Koerte et al., 2012), reports from rehabilitation centres or case managers (e.g., Ponsford et al., 2014), or neuroimaging (e.g., Grossman et al., 2012), for example. However, there has been sufficient evidence to suggest that obtaining MHI information via self-report is valid and representative (e.g., Baker & Good, 2014; Belanger et al., 2010). Moreover, none of the individuals who reported a history of MHI were involved in any form of litigation due to their injury; therefore, it can be assumed that the influence of incentive on an individual's motivation to exaggerate his/her symptoms is minimized. It is also noteworthy that participants in the current study were not recruited on the basis of head injury status; this was intentional so as to avoid the influence of diagnosis threat. It has been demonstrated that when individuals are recruited for head injury status, it may bias their responding and performance on particular tasks (see Suhr & Gunstad, 2002; 2005). Instead, individuals in the current study were recruited to participate in a study *"Investigating Individual Differences Between Athletes and Non-athletes"*.

Despite the fact that individuals were not recruited as a function of their head injury status, approximately 42% of participants reported having experienced a previous MHI sufficient to alter his/her consciousness, the majority of which were sustained during a sport-related activity (primarily ice-hockey, a high-risk sport). Also, all individuals with a history of MHI, except one, had surpassed the acute stage of injury (i.e., at least three months postinjury); twelve reported experiencing more than one MHI. In general, individuals with a history of MHI reported symptoms (e.g., headaches) commonly associated with post-concussion for a longer duration, increased intensity, and at a greater frequency than individuals without a history of MHI.

Participants were also classified on the basis of what sport they were currently playing. This classification was examined to clarify whether personality characteristics associated with MHI are primarily due to the injury itself or instead more attributed to pre-morbid personality. As aforementioned, athletes generally display elevated levels of certain traits (i.e., sensation seeking, aggression, and competitiveness; e.g., Ahmadi et al., 2011; Potgieter & Bisschoff, 1990; Zuckerman, 1983). Furthermore, athletes, particularly high-risk ones, have a greater vulnerability for sustaining a concussive injury to the head. In our study, approximately one-third of the sample did not play any sports, one-third played low-risk sports, and one-third played high-risk sports. Notably, sex was not found to be a significant factor in the analyses, nor did participants differ greatly in terms of demographic variables across the MHI and athletic groups.

Sixty-four participants returned for the post-season testing session; there were similar ratios of individuals in the MHI and athletic groups as the original sample. Three individuals reported sustaining a MHI between the two testing sessions, all of whom were high-risk athletes.

The first hypothesis, that high-risk athletic status would be associated with more MHIs, was supported. This is consistent with previous literature investigating the frequency of MHI by athletic status and sport (e.g., Gessel et al., 2007; Vakil, 2005). Remarkably, 18 of the 24 high-risk athletes that were tested in the pre-testing session self-reported a history of at least one MHI. The question remains whether individuals who engage in high-risk activities have particular premorbid traits that lead them to sustain a MHI (e.g., sensation seeking), if the elevated frequency of MHIs is due to the nature of these activities and sports, or whether it is a combination of the two.

In terms of investigating neurocognitive function (attention, working memory, cognitive flexibility), individuals with and without a history of MHI did not differ. However, and consistent with the current findings, it has been demonstrated that physiological alterations persist long after the once expected recovery time of mTBI of seven to 10 days (e.g., McCrory et al., 2009) and after acute symptoms have abated (e.g., Baker & Good, 2014; Ryan & Warden, 2003), even when neuropsychological alterations can no longer be detected (e.g., Ling et al., 2012). This suggests that, while there are physiological alterations postinjury, perhaps measures are not sufficiently sensitive to detect neurocognitive alterations postinjury (e.g., Bigler 2013).

Notably, individuals with a history of MHI performed significantly faster on the WRAT-IV word reading test. Thus, this increase may indicate an advantage of preserved or enhanced resilience in persons with MHI who have managed to continue their education at the university level—their enhanced intellectual capacity may function as a neuroprotective factor—consistent with the phenomenon of a "Brain Reserve Capacity" and/or the "Cognitive Reserve" model (Satz, 2001; Stern, 2009). Alternatively, this may be an index of impulsivity. Since no accuracy advantage was found for any of the neuropsychological measures, it is unlikely that these students had an intellectual gain over students without a history of MHI. Unfortunately, we have no measures of preinjury performance; however, the WRAT word reading subtest has been shown to be an accurate estimate of premorbid intellectual capacity (e.g., Johnstone, Callahan, Kapila, & Bouman, 1996). When post-season scores were investigated, MHI status predicted post-season working memory (SDMT score) over participants' pre-season SDMT score. Notably, while there were only three participants who sustained a MHI between the two seasons; when their data were excluded from the analyses, the impact MHI status had on working memory performance lessened. This is particularly interesting, since working memory performance did not differ between the MHI groups in the pre-season testing session. Perhaps in more acute stages of injury post-MHI (i.e., the witnessed added influence of the three concussed subjects on performance outcome) and the possibility of acute subconcussive influences (i.e., sport-related impact forces against the body experienced in high-risk activities), there are corresponding decreases in neurocognitive function and with time, these changes abate.

Others have also failed to find differences between individuals with and without MHI on cognitive functioning after acute symptoms have abated. Levin, Li, McCauley, Hanten, Wilde, and Swank (2012) found that performance on the SDMT did not differentiate individuals three months postinjury. Ling et al. (2012) identified differences in white matter integrity (via DTI) between individuals with and without mTBI four months postinjury, but failed to find any neuropsychological differences between the two groups. Moreover, Brenner et al. (2010) determined that symptomatic individuals with blast-related mTBIs could not be differentiated from asymptomatic individuals with blast-related mTBIs six months postinjury. In a meta-analysis, Belanger et al. (2010) concluded that a single mTBI does not result in significantly decreased neuropsychological performance. However, they found that sustaining multiple self-reported mTBIs was associated with decreased performance on measures of delayed memory and executive function. In the current study, the number of head injuries sustained did not correlate with performance on any of the neuropsychological measures.

One possibility for the lack of findings on neuropsychological measures between individuals with and without a history of MHI is the sensitivity of the measures. In a review, Bigler (2013) stated that particular neuropsychological measures are not sensitive enough to detect any persistent changes post-mTBI (including sport-related concussions). He stated that, generally, individuals with and without MHI differ immediately postinjury, though most individuals return to baseline after symptoms have abated. Likewise, Belanger and Vanderploeg (2005) stated that the majority of neuropsychological dysfunction abates approximately 10 days postinjury. Though, this is debated in the literature (e.g., Ponsford et al., 2011).

Others (e.g., Segalowitz, Bernstein, & Lawson, 2001) have used various behavioural tasks and electroencephalogram (EEG) as an attempt to elucidate any differences between the groups. Segalowitz et al. (2001), Gosselin et al. (2012), and Ozen, Itier, Preston, and Fernandes (2013) all found that individuals with mTBI demonstrated a decreased P300 amplitude compared to controls; however, only Gosselin et al. (2012) also found that mTBI subjects performed worse on a working memory task.

Conversely, others (e.g., Scolaro Moser, Schatx, & Jordan, 2005) have found significant differences in performance on neuropsychological measures between individuals with and without a history of mTBI who have passed the acute recovery phase. Ponsford et al. (2011) also found that individuals with mTBI performed more poorly on the visual memory subtest of the ImPACT battery at three months postinjury. Admittedly, however, evidence of long-term cognitive challenges have been mixed in the literature thus far (e.g., Ponsford et al., 2011).

It has been noted that there is likely a subgroup of individuals that experiences persistent cognitive challenges post-MHI; these individuals may also experience prolonged PCS (e.g., Chen, Johnston, Collie, McCrory, & Ptito, 2007; Ryan & Warden, 2003). Chen et al. (2007) classified individuals with a previous mTBI as 'low PCS' (i.e., a score from six to 21) or 'high PCS' (i.e., a score from 22 to 84) and found that the individuals in the high group displayed decreased cognitive function compared to the low group. In the current study, the criteria used by Chen et al. (2007) could not be implemented as a different, shortened version of the PCS was administered. However, a median-split was performed on PCS for the MHI group, and no differences on neuropsychological performance were found.

One of the current objectives was to ascertain whether risky personality traits are primarily related to MHI or athletic status. Contrary to expectations, when MHI and athletic status were investigated, there were no differences for any aggression- or impulsivity-related variables. However, when MHI and athletic status were examined separately, individuals with a prior MHI endorsed higher levels of sensation seeking, physical aggression, and competitiveness compared to no MHI individuals, while both high- and low-risk athletes endorsed higher levels of sensation seeking and competitiveness compared to non-athletes. Therefore, there was no evidence to suggest that high-risk athletes have riskier personality traits than low-risk athletes; however, athletes overall had riskier personalities than non-athletes. This is in contrast to previous literature stating that high-risk athletes have higher levels of sensation seeking (e.g., Zuckerman, 1983) and aggression (e.g., Ahmandi et al., 2011; Ziaee et al., 2012) than low-risk and non-athletes.

Consistent with previous studies investigating personality post-TBI (e.g., Baugh et al., 2012; McHugh & Wood, 2008; Wong, 2011) and mTBI (e.g., Ferguson & Coccaro, 2009) that have reported differences in aggression and impulsivity, individuals with MHI in this study demonstrated a propensity for riskier personalities as well. Specifically, individuals with MHI presented with physical/reactive aggression, as opposed to overall aggression, hostility or anger. Similarly, they endorsed greater sensation seeking behaviour, as opposed to having an increase in overall impulsivity or a lack of premeditation or perseverance.

In addition, this is the first known documentation of differences in competitiveness between individuals with and without a history of MHI. Perhaps this finding is reflective of the underlying risk associated with the trait of competitiveness. For example, competitiveness is linked to reactive aggression (Carré, Gilchrist, Morrissey, & McCormick, 2010) and has been defined as the desire to engage in and strive for success (Crocker, 2007). Perhaps the competitiveness observed in the individuals with a history of MHI depicts these riskier aspects. While approximately 80% of the individuals in the current study who reported a history of MHI were also athletes (either low- or high-risk) endorsed competitiveness was primarily attributed to MHI beyond athletic status.

Interestingly, individuals with a history of MHI displayed physiological underarousal as indicated by decreased EDA compared to those without a history of MHI. Electrodermal activation has been demonstrated to be a sensitive proxy of sympathetic nervous system (SNS) function (Lazarus et al., 1963); perhaps this is evidence that individuals with MHI have subtle SNS dysfunction. Besides EDA, there were no other differences in physiological arousal based on MHI status, despite the fact that other measures, such as HRV, are thought to be indicative of ANS function (e.g., Sztajzel, 2004). The only difference in physiological arousal associated with athletic status was heart rate, such that high-risk athletes demonstrated a lower resting heart rate than non-athletes. This is consistent with previous literature indicating that athletes generally exhibit lower resting heart rates compared to non-athletes (e.g., Aubert, Beckers, & Raemaekers, 2001).

It is possible that the MHI group acknowledged higher levels of risky personality, such as sensation seeking, competitiveness, and physical aggression, due to physiological underarousal. In other words, individuals who are physiologically less aroused or alert may engage in activities that are more likely to increase or excite their SNS. The fifth hypothesis, that risky personality traits are associated with lowered physiological arousal, addresses this in part. Mild head injury status predicted physiological arousal over and above the various personality traits. In separate analyses, while indeed sensation seeking, aggression, and verbal and physical aggression significantly predicted EDA amplitude, MHI status reached, or approached, significance over and above the personality traits. Further, while several researchers have suggested that high-risk athletes and individuals who have high levels of sensation seeking and/or impulsivity are generally arousal-seekers – in that, they participate in particular risky activities to increase their arousal levels (Kerr, 1991; Zuckerman, 1983), the current study found that overall impulsivity did not predict arousal whatsoever; in fact, MHI status predicted arousal over and above impulsive personality traits.

It has also been suggested that physiological arousal and reactive aggression are related. In sum, there are two broad kinds of aggression: proactive and reactive (Baron & Richardson, 2004). It has been stated that heightened physiological arousal is associated with reactive aggression, but not proactive aggression, which leaves the individual disinhibited (see Tyson, 1998 for a review). In this study, individuals with MHI endorsed more items that were consistent with a reactive, physical, aggression relative to their no MHI cohort, but not those indicative of proactive, hostile or angry aggression. This reactivity may be related to their lowered baseline physiological arousal. In a manner similar to individuals who have moderate to severe injury to the VMPFC (which can disrupt the ability to regulate SNS activation; Wallis, 2007) and the OFC (which has been associated with decreased ability to produce anticipatory physiological feedback signals; Bechara, Tranel, Damasio, & Damasio, 1996), individuals with MHI may overreact to unanticipated outcomes and consequences (e.g., Cattran et al., 2011). Cattran et al. (2011) have stated that a hallmark observation post-TBI is the expression of impulsive behaviour and/or poor temper/emotional control due to disruption of the OFC. Individuals with MHI may be rendered less able to elicit anticipatory signals and regulate sympathetic activation, similar to individuals with more severe injuries.

Consistent with the above, van Noordt and Good (2011) found that university students with self-reported MHI demonstrated lower physiological arousal compared to control participants in anticipation of making a decision on a gambling task. Decreased anticipatory physiological arousal may render subjects to be less prepared when something unexpected and/or salient occurs in the environment. These individuals may overreact resulting in a disproportionate increase in arousal—perhaps overshooting optimal arousal levels (see Yerkes & Dodson, 1908). Related literature has shown that impulsive individuals are underaroused at rest, but experience disproportionate increases in arousal in response to stimulation (Mathias & Standford, 2003); and due to their sudden increase in arousal, individuals may respond in a reactively aggressive manner. As previously mentioned, the physical aggression subscale of the BPAQ is also reflective of reactive aggression. Perhaps individuals with milder head injuries do not necessarily have aggressive personalities; rather, this personality-like alteration postinjury is a reflection of lowered physiological arousal and a subsequent responding to unanticipated stimuli in the environment. It is unlikely that this change postinjury is simply due to a premorbid aggressive personality, as high- and low-risk athletes did not differ in terms of personality measures.

Similarly, the only subscale of the UPPS-P Impulsive Scale that differed between individuals with and without a previous MHI was the sensation seeking subscale, regardless of athletic status. Individuals did not endorse a lack of premeditation or perseverance, for instance. Perhaps individuals are attempting to enhance their level of vigilance and alertness (i.e., physiological arousal) post-MHI but, as a consequence, present with/endorse risk-taking-like behaviours. Notably, sensation seeking was significantly, and negatively, correlated with physiological arousal (i.e., EDA). Thus, individuals with MHI ought not to be considered necessarily impulsive in terms of personality, but rather should be viewed as individuals who have a tendency to endorse activity that can increase their physiological arousal.

The aforementioned analyses have been interpreted as possibly indicating that the personality alterations post-MHI are due to the injury itself and its associated decrease in physiological arousal, as opposed to simply representing premorbid characteristics *per se*; however the sixth and final hypothesis was, unfortunately, unable to confirm this. The aim of the two-part methodological design was to enable an examination of individuals pre- and post-acute concussion. Unexpectedly, only three individuals sustained a MHI during the course of testing (i.e., between the pre- and post-season testing sessions), each of whom had reported a history of at least one prior MHI pre-season. There were no individuals who entered the study without a MHI and subsequently sustained a MHI over the duration of testing. Further, the fact that only three individuals sustained a subsequent MHI disallowed the planned analyses due to power issues.

The challenges surrounding analyses for the sixth hypothesis reveal limitations to the current study. One of the major objectives of the current study was to determine whether premorbid characteristics influence postinjury outcomes after an individual sustains a MHI. To do this, a pre-post design was used, but did not succeed at identifying suitable subjects. Had additional or longitudinal testing sessions been employed, more participants may have sustained new MHIs. Furthermore, the majority of the high-risk athletes in the current study had a prior MHI upon entering the study; if children or youth, perhaps as young as 10 (contact sports typically begin around the ages of 11 to 13; Macpherson, Rothman, & Howard, 2006) were tested, there would be a higher probability of witnessing a participants' first MHI. Furthermore, in the pre-season testing session, there were unequal numbers of participants with and without a history of MHI in the three athletic groups (i.e., non-athlete, low-risk athlete, high-risk athlete)[5]. Specifically, and as expected, the majority of individuals with a previous MHI were classified as high-risk athletes. Perhaps if more individuals participated in the study, the discrepancy in the number of persons in each athletic category with a history of MHI would have been reduced. For example, perhaps more non-athletes would have sustained a MHI. However, given the nature of high-risk sports (e.g., Vakil, 2005), the current sample may indeed reflect the general population, in that current or former high-risk athletes are more likely to sustain a MHI than low-risk and non-athletes. This warrants further investigation.

Another limitation of the current study is the lack of generalizability. The current sample consisted of university students and disproportionately more athletes than previous studies, or the general population, due to recruitment methods (i.e., recruiting exclusively university students and specifically for a study investigating "Individual Differences Between Athletes and Non-athletes"; contacting athletic teams directly).

[5] To address the unequal number of participants in each group, as abovementioned, the Tukey-Kramer approach was used when post-hoc analyses were performed (see Kramer, 1956). Furthermore, there were no violations for the assumption of homogeneity of variance when the ANOVAs were computed (see Howell, 2013), nor for the assumption of homoscedasticity when regressions were calculated (see Cohen, Cohen, West, & Aiken, 2003), unless otherwise stated.

University students are a subgroup of individuals that are typically younger, more educated, and have a higher socioeconomic status than the general population. Furthermore, all participants were currently living in a particular geographic area. Satz (2001) has argued for a "Brain Reserve Capacity" and Stern (2009) has promoted a "Cognitive Reserve" model, both emphasizing the resilience and compensatory capacity of persons with advantaged intellectual capacity as being neuroprotective for subsequent concussion and trauma to the brain. Therefore, the current sample was not entirely randomly selected and necessarily does not reflect the general population (e.g., Henrich,, Heine, & Norenzayan, 2010; Saltz, 2001; Stern, 2009). Moreover, while sport-related activities are a common etiology of MHI for adolescents and young adults, falls and MVCs are a more prominent etiology of MHI for other age groups (e.g., children and older adults). This also limits the generalizability of the current findings to other MHI age groups.

Due to the fact that the only physiological measure that differed as a function of MHI status was EDA, it may be useful to include a measure of vagal tone. Vagal tone is thought to be a more sensitive measure than other physiological measures that were included in the study (e.g., HRV), as vagal tone directly contributes to/underlies HRV (e.g., Berntson, 1997). A measure of vagal tone would also provide a proxy of neurological function (i.e., vagus nerve function). Given that the personality alterations observed postinjury are thought to be reflective of decreased physiological arousal, the investigation of another sensitive physiological measure may be beneficial.

Finally, it may have been beneficial to include observational, objective tasks of aggression, risk-taking, and competitiveness in addition to the self-report questionnaires that were administered in the current study. Despite the fact that all of the questionnaires included in the study were reliable and valid, a more direct measure of the investigated personality traits would have provided corroborating evidence demonstrating how an individual responds to stimuli and events rather than what they 'think' they do – insight to our own behaviour is not always representative, or available. Likewise, head injury status was obtained using self-report – requiring memory and accuracy of description. Obtaining medical records would provide additional, pertinent and possibly more accurate, or otherwise confirmatory, information. That said, as previously noted, self-report methodology has been demonstrated to be a valid measure of head injury status (e.g., Belander, Spiegel, & Vanderploeg, 2010). Further, formal documentation of MHI may underestimate a subject's status due to most individuals failing to seek medical attention postinjury; thus, validation through medical supports may be unavailable and uninformative (e.g., Meehan & Mannix, 2010).

Future research should include additional follow-up sessions in a longitudinal study design—a longitudinal design would allow researchers to better investigate changes that occur post-MHI and throughout development. Furthermore, the sample should be expanded to include both children and older adults. The inclusion of children will be particularly important in attempting to ascertain the influence of premorbid traits on postinjury outcome, as there is a greater likelihood that the subjects will not have experienced a MHI upon entering the study. In addition, the inclusion of observed behavioural, potentially manipulated, measures of aggression, impulsivity, and competitiveness would be beneficial, such as the PSAP (Cherek, 1981).

Conclusions

In sum, despite the fact that the design did not produce the subject sample as planned, the current study begins to inform the issue of personality-based influences on postinjury outcome after MHI. Specifically, as expected, high-risk athletes sustained more self-reported MHIs than low-risk and non-athletes. However, high-risk athletes were not found to have riskier personalities than low-risk and non-athletes. On the other hand, individuals with previous MHI endorsed higher levels of physical/reactive aggression, competitiveness, and sensation seeking compared to those without a history of MHI. Individuals with a previous MHI were also physiologically underaroused compared to those without previous MHI (via EDA). In addition, risky personality traits were associated with physiological arousal, though MHI predicted physiological arousal over and above the athletic status and risky personality. Lastly and unexpectedly, individuals with a history of MHI did not perform worse on measures of neurocognitive function compared to those without a previous MHI.

It has been proposed that personality alterations post-MHI may be best characterized as subsequent sequelae as a result of altered physiological arousal. At least for persons with milder head injuries, and in contrast to previous research (e.g., Ferguson & Coccaro, 2009; Goswami et al., 2015), there are no overall, or generic, increases in impulsivity or aggression associated with head injury. Instead, there are specific changes in behaviour (i.e., physical/reactive aggression and sensation seeking) that reflect aggression and/or impulsivity, but are perhaps a consequence of lowered physiological arousal.

It was somewhat unexpected that individuals with previous MHI endorse increased levels of competitiveness compared to individuals without MHI; perhaps the questionnaire used to measure competitiveness was capturing those underlying and related risk-taking/aggressive aspects of competitive behaviour (e.g., Carre et al., 2010). Importantly, there was no evidence that individuals with a history of MHI are simply more aggressive, hostile, angry, impulsive, or lack premeditation, urgency, or perseverance compared to their non-injured cohort.

The categorization of individuals into various athletic groups was crucial, as it is has been stated that athletes who engage in risky sports have specific personality traits, including aggression and impulsivity/sensation seeking (e.g., Cronin, 1991; Sonderlund et al., 2014). Further, as the incidence of MHI is quite high in athletic populations, it has been suggested that these particular risky personality traits specifically put individuals at risk for injury. As a result, personality is confounded with the resulting MHI and researchers are simply observing the consequence of an individuals' risky premorbid personality trait(s). Importantly, in the current study, and in contrast to previous studies, high- and low-risk athletes did not differ on any of the personality traits that were investigated, but did differ in their incidence of MHI (consistent with previous research; e.g., Gessel et al., 2007); and physiological underarousal, as measured by EDA, was related specifically to MHI, even after other factors such as personality and athletic status were considered and evaluated. Additionally, there were no differences in intellectual capacity based on head injury status. This provides evidence for a lack of premorbid differences on this dimension between the MHI and no MHI groups since crystallized measures of intellectual capacity, including the vocabulary measures such as the WRAT word reading test (which was administered in the current study), are accurate predictors of premorbid intellectual capacity (e.g., Johnstone et al., 1996). This serves as preliminary evidence that changes that are observed postinjury are in fact, at least in part, due to the neurological/physiological status associated with MHI.

Implications of the current study are two-fold. Firstly, based on the physiological and PCS data and its relationship to reported MHIs that occurred several months (to years) pre-testing there is evidence of persistent, long-term consequences and symptoms resulting from milder injuries to the head. Secondly, decreased physiological arousal (via EDA) may be the key to understanding how to improve postinjury outcomes. If personality-like changes post-MHI are a function of physiological alterations from the injury, in part, then interventions and treatment programs that target underarousal may lead to better outcomes or presentations (i.e., less overreactivity, less risky behaviours).

Taken together, the current study provides preliminary evidence that injury to the head and its associated subsequent physiological underarousal contribute to personality-like changes observed post-MHI. Further, there is evidence that some of the outcomes reported post-TBI also occur post-MHI, albeit to a lesser degree. Finally, these 'mild' injuries can have persistent, yet subtle, long-term alterations in physiology and behaviour.

References

Abbas, K., Shenk, T. E., Poole, V. N., Breedlove, E. L., Leverenz, L. J., Nauman, E. A., … Robinson, M. E. (2014). Alteration of Default Mode Network in high school football athletes due to repetitive subconcussive Mild Traumatic Brain Injury: A resting-state functional magnetic resonance imaging study. *Brain Connectivity*, *5*(2), 91-101. doi:10.1089/brain.2014.0279

Abrahams, S., McFie, S., Patricios, J., Posthumus, M., & September, A. V. (2013). Risk factors for sports concussion: an evidence-based systematic review. *British Journal of Sports Medicine*, 1–9. doi:10.1136/bjsports-2013-092734

Ahmadi, S. S., Besharat, M. A., Azizi, K., & Larijani, R. (2011). The relationship between dimensions of anger and aggression in contact and noncontact sports. *Procedia - Social and Behavioral Sciences*, *30*, 247–251. doi:10.1016/j.sbspro.2011.10.049

Alt, C. A. (1999). *The relationship among attention-deficit/hyperactivity disorder (ADHD), personality type and creativity in adults using the Myers-Briggs Type Indicator (MBTI) and the Torrance Tests of Creative Thinking (TTCT)* (Doctoral dissertation, ProQuest Information & Learning).

Andrews, T. K., Rose, F. D., & Johnson, D. A. (1998). Social and behavioural effects of traumatic brain injury in children. *Brain Injury, 12*, 133-138.

Aubert, A. E., Beckers, F., & Ramaekers, D. (2000). Short-term heart rate variability in young athletes. *Journal of Cardiology*, *37*, 85-88.

Bailes, J. E., Petraglia, A. L., Omalu, B. I., Nauman, E., & Talavage, T. (2013). Role of subconcussion in repetitive mild traumatic brain injury. *Journal of Neurosurgery*, *119*(5), 1235–45. doi:10.3171/2013.7.JNS121822

Baker, J. & Good, D. (2014). Physiological emotional under-arousal in individuals with mild head injury. *Brain Injury, 28*(1), 1-15. doi: 10.3109/02699052.2013.857787

Bara Filho, M.G., Scipi o Ribeiro, L. C., & García, F. G. (2005). Comparison of personality characteristics between high-level Brazilian athletes and non-athletes. *Revista Brasileira de Medicina do Esporte*, *11*(2), 114-118.

Baron, R. A. & Richardson, D. R. (2004). Human aggression. New York: Plenum Press.

Barr, W. B. & McCrea, M. (2001). Sensitivity and specificity of standardized neurocognitive testing immediately following sports concussion. *Journal of the International Neuropsychological Society*, *7*(6), 693–702.

Baugh, C. M., Stamm, J. M., Riley, D. O., Gavett, B. E., Shenton, M. E., Lin, A., … Stern, R. A. (2012). Chronic traumatic encephalopathy: Neurodegeneration following repetitive concussive and subconcussive brain trauma. *Brain Imaging and Behavior*, *6*(2), 244–54. doi:10.1007/s11682-012-9164-5

Bazarian, J. J., Cernak, I., Noble-Haeusslein, L., Potolicchio, S., & Temkin, N. (2009). Long-term neurologic outcomes after traumatic brain injury. *The Journal of Head Trauma Rehabilitation*, *24*(6), 439-451.

Bazarian, J. J., Zhu, T., Blyth, B., Borrino, A., & Zhong, J. (2012). Subject-specific changes in brain white matter on diffusion tensor imaging after sports-related concussion. *Magnetic Resonance Imaging*, *30*(2), 171–80. doi:10.1016/j.mri.2011.10.001

Bechara, A., Tranel, D., Damasio, H., & Damasio, A. R. (1996). Failure to respond autonomically to anticipated future outcomes following damage to prefrontal cortex. *Cerebral cortex*, *6*(2), 215-225.

Belanger, H. G., Curtiss, G., Demery, J. A., Lebowitz, B. K., & Vanderploeg, R.D. (2005). Factors moderating neuropsychological outcome following mild traumatic brain injury: A meta analysis. *Journal of the International Neuropsychological Society, 11*, 215–227.

Belanger, H. G., Spiegel, E., & Vanderploeg, R. D. (2010). Neuropsychological performance following a history of multiple self-reported concussions: A meta-analysis. *Journal of the International Neuropsychological Society*, *16*(2), 262–267. doi:10.1017/S1355617709991287

Belanger, H. G. & Vanderploeg, R. D. (2005). The neuropsychological impact of sports-related concussion: a meta-analysis. *Journal of the International Neuropsychological Society*, *11*(4), 345–57.

Benarroch, E. E. (1993). The central autonomic network: functional organization, dysfunction, and perspective. *Mayo Clinic Proceedings*, *68*(10), 988-1001. doi:10.1016/S0025-6196(12)62272-1

Berntson, G. G., Bigger, J. T., Eckberg, D. L., Grossman, P., Kaufmann, P. G., Malik, M., ... & Van Der Molen, M. W. (1997). Heart rate variability: origins, methods, and interpretive caveats. *Psychophysiology*, *34*(6), 623-648.

Bigler, E. D. (2013). Neuroimaging biomarkers in mild traumatic brain injury (mTBI). *Neuropsychology Review*, *23*(3), 169-209. doi:10.1007/s11065-013-9237-2

Bigler, E. D. (1999). Neuroimaging in pediatric traumatic head injury: diagnostic considerations and relationships to neurobehavioral outcome. *The Journal of Head Trauma Rehabilitation*, *14*(4), 406-423.

Bigler, E. D., Andersob, C. V., & Blatter, D. D. (2002). Temporal lobe morphology in normal aging and traumatic brain injury. *American Journal of Neuroradiology*, *23*(2), 255-266.

Bigler, E. D. & Brooks, M. (2009). Traumatic brain injury and forensic neuropsychology. *The Journal of head trauma rehabilitation*, *24*(2), 76-87. doi:10.1097/HTR.0b013e31819c2190

Blair, R. J. R. (2004). The roles of orbital frontal cortex in the modulation of antisocial behavior. *Brain and cognition*, *55*(1), 198-208.

Bleiberg, J., Cernich, A. N., Cameron, K., Sun, W., Peck, K., Ecklund, L. P. J., ... & Warden, D. L. (2005). Duration of cognitive impairment after sports concussion. *Neurosurgery*, *54*(5), 1073-1080.

Bloemsma, J. M., Boer, F., Arnold, R., Banaschewski, T., Faraone, S. V., Buitelaar, J. K., ... & Oosterlaan, J. (2013). Comorbid anxiety and neurocognitive dysfunctions in children with ADHD. *European child & adolescent psychiatry*, *22*(4), 225-234. doi:10.1007/s00787-012-0339-9

Booth, A., Cardona-Sosa, L., & Nolan, P. (2014). Gender differences in risk aversion: Do single-sex environments affect their development? *Journal of Economic Behavior and Organization, 99*, 126-154.

Brenner, L. A., Terrio, H., Homaifar, B. Y., Gutierrez, P. M., Staves, P. J., Harwood, J. E., ... & Warden, D. (2010). Neuropsychological test performance in soldiers with blast related mild TBI. *Neuropsychology*, *24*(2), 160.doi:10.1037/a0017966

Broglio, S. P., Cantu, R. C., Gioia, G. A., Guskiewicz, K. M., Kutcher, J., Palm, M., & McLeod, T. C. V. (2014). National Athletic Trainers' Association Position Statement: Management of Sport Concussion. *Journal of Athletic Training*, *49*(2). doi:10.4085/1062-6050-49.1.07

Buss, A. H. & Perry, M. (1992). The aggression questionnaire. *Journal of Personality and Social Psychology, 63(3)*, 452-459.

Cantu, R. (1998). Second-impact syndrome. *Clinical Sports Medicine, 17*, 37–44. doi:10.1016/S0278-5919(05)70059-4

Carré, J. M., Gilchrist, J. D., Morrissey, M. D., & McCormick, C. M. (2010). Motivational and situational factors and the relationship between testosterone dynamics and human aggression during competition. *Biological Psychology*, *84*(2), 346–53. doi:10.1016/j.biopsycho.2010.04.001

Carroll, L., Cassidy, J. D., Peloso, P., Borg, J., Von Holst, H., Holm, L., ... & Pépin, M. (2004). Prognosis for mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *Journal of Rehabilitation Medicine*, *36*, 84-105. doi:10.1080/16501960410023859

Cassidy, J. D., Carroll, L., Peloso, P., Borg, J., Von Holst, H., Holm, L., … & Coronado, V. (2004). Incidence, risk factors and prevention of mild traumatic brain injury: Results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *Journal of Rehabilitation Medicine, 36*(0), 28-60.

Cattran, C., Oddy, M., & Wood, R. (2011). The development of a measure of emotional regulation following acquired brain injury. *Journal of Clinical and Experimental Neuropsychology*, *33*(6), 672–679. doi:10.1080/13803395.2010.550603

Cazenave, N., Le Scanff, C., & Woodman, T. (2007). Psychological profiles and emotional regulation characteristics of women engaged in risk-taking sports. *Anxiety, Stress, and Coping*, *20*(4), 421–435. doi:10.1080/10615800701330176

Centers for Disease Control (CDC). (2007). National Center for Injury Prevention and Control: Traumatic Brain Injury. http :// www.cdc.gov/ncipc/factsheets/tbi.htm

Chen, J. K., Johnston, K. M., Collie, A., McCrory, P., & Ptito, A. (2007). A validation of the post concussion symptom scale in the assessment of complex concussion using cognitive testing and functional MRI. *Journal of Neurology, Neurosurgery, and Psychiatry*, *78*(11), 1231–8. doi:10.1136/jnnp.2006.110395

Cherek, D. (1981). Effects of smoking different doses of nicotine on human aggressive behavior. *Psychopharmacology 75*, 339–345.

Coccaro, E. F., Berman, M. E., & Kavoussi, R. J. (1997). Assessment of life history of aggression: Development and psychometric characteristics. *Psychiatry Research*, *73*(3), 147-157.

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2013). *Applied multiple regression/ correlation analysis for the behavioral sciences*. Routledge: New York.

Collins, R. L., Pastorek, N. J., Tharp, A. T., & Kent, T. A. (2012). Behavioral and psychiatric comorbidities of TBI. In *Traumatic Brain Injury*, 223-244: Springer New York.

Costa, P. T. & McCrae, R. R. (1992). Neo PI-R Professional Manual.

Covassin, T., Swanik, C. B., Sachs, M., Kendrick, Z., Schatz, P., Zillmer, E., & Kaminaris, C. (2006). Sex differences in baseline neuropsychological function and concussion symptoms of collegiate athletes. *British Journal of Sports Medicine*, *40*(11), 923–927. doi:10.1136/bjsm.2006.029496

Craig, K. D. (1968). Physiological arousal as a function of imagined, vicarious, and direct stress experiences. *Journal of Abnormal Psychology, 73(6)*, 513-520. doi:10.1037/h0026531

Crisco, J. J., Wilcox, B. J., Beckwith, J. G., Chu, J. J., Duhaime, A. C., Rowson, S., … Greenwald, R. M. (2011). Head impact exposure in collegiate football players. *Journal of Biomechanics*, *44*(15), 2673–8. doi:10.1016/j.jbiomech.2011.08.003

Crocker, P. (2007). Sport and Exercise Psychology. Pearson Canada: Toronto, Ontario.

De Beaumont, L., Theoret, H., Mongeon, D., Messier, J., Leclerc, S., Tremblay, S., … & Lassonde, M. (2009). Brain function decline in healthy retired athletes who sustained their last sports concussion in early adulthood. *Brain, 132*(3), 695-708. doi: 10.1093/brain/awn347

Dean, P. J. & Sterr, A. (2013). Long-term effects of mild traumatic brain injury on cognitive performance. *Frontiers in Human Neuroscience*, *7*, 30. doi:10.3389/fnhum.2013.00030

Delaney, J. S., Puni, V., & Rouah, F. (2006). Mechanisms of injury for concussions in university football, ice hockey, and soccer: A pilot study. *Clinical Journal of Sport Medicine*, *16*(2), 162-165.

Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan executive function system (D-KEFS)*. Psychological Corporation.

Delis-Kaplan Executive Function System (2002). San Antonio, Texas: Harcourt Assessment.

Diamond, P. M. & Magaletta, P. R. (2006). The short-form Buss-Perry Aggression Questionnaire (BPAQ-SF): A validation study with federal offenders. *Assessment*, *13*(3), 227–240. doi:10.1177/1073191106287666

Dienstbier, R. A. (1989). Arousal and physiological toughness: Implications for mental and physical health. *Psychological Review*, *96*(1), 84.

Doolan, A. W., Day, D. D., Maerlender, A. C., Goforth, M., & Gunnar Brolinson, P. (2012). A review of return to play issues and sports-related concussion. *Annals of Biomedical Engineering*, *40*(1), 106–113. doi:10.1007/s10439-011-0413-3

Dougan, B., Horswill, M., & Geffen, G. (2014). Athletes' age, sex, and years of education moderate the acute neuropsychological impact of sports-related concussion: A meta-analysis. *Journal of the International Neuropsychological Society, 20*, 64–80. doi:10.1017/S1355617712001464

Dryer, K. F., Bell, R., McCann, J., & Rauch, R. (2006). Aggression after traumatic brain injury: Analysing socially desirable responses and the nature of aggressive traits. *Brain Injury*, *20*(11), 1163-1173.

Echemendia, R. J., Putukian, M., Mackin, R. S., Julian, L., & Shoss, N. (2001). Neuropsychological test performance prior to and following sports-related mild traumatic brain injury. *Clinical Journal of Sport Medicine, 11*(1), 23-31.

Emery, C. A., Goulet, C., Hagel, B. E., Benson, B. W., Nettel-Aguirre, A., McAllister, J. R., … Meeuwisse, W. H. (2014). Risk of injury associated with body checking among youth hockey players. *Journal of the American Medical Association*, *303*(22), 2265–2272.

Erdal, K. (2012). Neuropsychological testing for sports-related concussion: How athletes can sandbag their baseline testing without detection. *Archives of Clinical Neuropsychology : The Official Journal of the National Academy of Neuropsychologists*, *27*(5), 473–9. doi:10.1093/arclin/acs050

Ferguson, S. D. & Coccaro, E. F. (2009). History of mild to moderate traumatic brain injury and aggression in physically healthy participants with and without personality disorder. *Journal of Personality Disorders*, *23*(3), 230–239.

Fisher, A. J., Granger, D. A., & Newman, M. G. (2010). Sympathetic arousal moderates self-reported physiological arousal symptoms at baseline and physiological flexibility in response to a stressor in generalized anxiety disorder. *Biological Psychology*, *83*(3), 191-200. doi:10.1016/j.biopsycho.2009.12.007

Fisher, R. A. (1948). Statistical Methods for Research Workers. New York: Hafner.

Fowles, D. C. (1974). Mechanisms of electrodermal activity. *Methods in Physiological Psychology, 1*, 231–271.

Gessel, L. M., Fields, S. K., Collins, C. L., Dick, R. W., & Comstock, R. D. (2007). Concussions among United States high school and collegiate athletes. *Journal of Athletic Training*, *42*(4), 495–503. doi:10.1016/S0162-0908(08)79294-8

Gill, D. L. & Deeter, T. E. (1988). Development of the Sport Orientation Questionnaire. *Research Quarterly for Exercise and Sport, 59*, 191-202.

Giza, C. C. & Hovda, D. A. (2001). The neurometabolic cascade of concussion. *Journal of Athletic Training*, *36*(3), 228–235.

Gorman, L. K., Fu, K., Hovda, D. A., Murray, M., & Traystman, R. J. (1996). Effects of traumatic brain injury on the cholinergic system in the rat. *Journal of Neurotrauma, 13*, 457-463.

Gosselin, N., Bottari, C., Chen, J. K., Huntgeburth, S. C., De Beaumont, L., Petrides, M., … Ptito, A. (2012). Evaluating the cognitive consequences of mild traumatic brain injury and concussion by using electrophysiology. *Neurosurgical Focus*, *33*(6), 1–7. doi:10.3171/2012.10.FOCUS1225

Goswami, R., Dufort, P., Tartaglia, M. C., Green, R. E., Crawley, A., Tator, C. H., ... & Davis, K. D. (2015). Frontotemporal correlates of impulsivity and machine learning in retired professional athletes with a history of multiple concussions. *Brain Structure and Function*, 1-15. doi: 10.1007/s00429-015-1012

Gouvier, W. D., Cubic, B., Jones, G., Brantley, P., & Cutlip, Q. (1992). Postconcussion symptoms and daily stress in normal and head-injured college populations. *Archives of Clinical Neuropsychology*, *7*(3), 193-211.

Grafman, J., Schwab, K., Warden, D., Pridgen, A., Brown, H. R., & Salazar, M. (1996). Frontal lobe injuries, violence, and aggression: A report of the Vietnam Head Injury Study. *Neurology*, *46*(5), 1231–1238.

Gronwall, D. M. A. (1977). Paced auditory serial-addition task: A measure of recovery from concussion. *Perceptual and Motor Skills*, *44*(2), 367-373.

Grossman, E. J., Ge, Y., Jensen, J. H., Babb, J. S., Miles, L., Reaume, J., Silver, J. M., Grossman, R. I., & Inglese, M. (2012). Thalamus and cognitive impairment in mild traumatic brain injury: A diffusional kurtosis imaging study. *Journal of Neurotrauma, 29*(13), 2318-2327. doi:10.1089/neu.2011.1763.

Grossman, S. & Hines, T. (1996). National hockey league players from North America are more violent than those from Europe. *Perceptual and Motor Skills, 83*, 589−590.

Hall, R. C. W., Hall, R. C. W., & Chapman, M. J. (2005). Definition, diagnosis, and forensic implications of postconcussional syndrome. *Psychosomatics, 46*, 195-202. doi:10.1176/appi.psy.47.3.272.

Henrich, J., Jeine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and Brain Sciences, 33*(2-3), 61-83. doi:10.1017/S0140525X0999152X

Henry G. K. (1994). DSM-IV: Proposed criteria for postconcussive disorder. *Journal of Neuropsychiatry & Clinical Neurosciences, 6*, 58–59.

Henry, L. C., Tremblay, S., Boulanger, Y., Ellemberg, D. & Lassonde, M. (2010). Neurometabolic changes in the acute phase after sports concussions correlate with symptom severity. *Journal of Neurotrauma, 27(1),* 65-76. doi:10.1089/neu.2009.0962

Hopkins M. J., Dywan J., & Segalowitz S. J. (2002). Altered electrodermal response to facial expression after closed head injury. *Brain Injury, 16*, 245–257.

Houston, J. M., Harris, P. B., McIntire, S., & Francis, D. (2002) Revising the Competitiveness Index. *Psychological Reports, 90*, 31-34.

Houston, R. J. & Stanford, M. S. (2001). Mid-latency evoked potentials in self-reported impulsive aggression. *International Journal of Psychophysiology*, *40*(1), 1-15.

Houston, R. J. & Stanford, M. S. (2005). Electrophysiological substrates of impulsiveness: Potential effects on aggressive behavior. *Progress in Neuro-Psychopharmacology & Biological Psychiatry*, *29*(2), 305–313.

Howell, D. (2012). *Statistical methods for psychology*. Wadsworth, Cengage Learning: Belmont.

Huang, D. B., Cherek, D. R., & Lane, S. D. (1999). Laboratory measurement of aggression in high school age athletes: Provocation in a nonsporting context. *Psychological Reports, 85*, 1251−1262. doi:10.2466/pr0.1999.85.3f.1251

Iverson, G. L. & Lange R. T. (2009). Moderate and severe traumatic brain injury. In M.R. Schoenberg & J.G. Scott J. G., (eds), The black book of neuropsychology: A syndrome based approach. New York: Springer.

Johnstone, B., Callahan, C. D., Kapila, C. J., & Bouman, D. E. (1996). The comparability of the WRAT-R reading test and NAART as estimates of premorbid intelligence in neurologically impaired patients. *Archives of Clinical Neuropsychology, 11*(6), 513-519. doi:10.1093/arclin/11.6.513

Kang, L., Gill, D. L., Acevedo, E. O., & Deeter, T. E. (1991). Competitive orientations among athletes and nonathletes in Taiwan. *International Journal of Sport Psychology, 21(2)*, 146-157.

Kaut K. P., DePompei R., Kerr J., Congeni, J. (2003). Reports of head injury and symptom knowledge among college athletes: Implications for assessment and educational intervention*. Clinical Journal of Sport Medicine, 13(4),*213–221.

Kay, T., Harrington, D. E., Adams, R., Anderson, T., Berrol, S., Cicerone, K., Dahlberg, C., Gerber, D., Goka, R., Harley, P., et al. (1993). Mild Traumatic Brain Injury Committee, American Congress of Rehabilitation Medicine, Head Injury Interdisciplinary Special Interest Group. Definition of mild traumatic brain injury. *Journal of Head Trauma Rehabilitation, 8*, 86–87.

Keeler, L. A. (2007). The differences in sport aggression, life aggression, and life assertion among adult male and female collision, contact, and non-contact sport athletes. *Journal of Sport Behavior, 30*(1), 57−76.

Kerr, H. A. (2014). Concussion risk factors and strategies for prevention. *Pediatric Annals*, *43*(12), e309–e315. doi:10.3928/00904481-20141124-10

Kerr, J. H. (1991). Arousal-seeking in risk sport participants. *Personality and individual Differences*, *12*(6), 613-616.

Killam, C., Cautin, R. L., & Santucci, A. C. (2005). Assessing the enduring residual neuropsychological effects of head trauma in college athletes who participate in contact sports. *Archives of Clinical Neuropsychology*, *20*(5), 599-611.

Kolitz, B. P., Vanderploeg, R. D., & Curtiss, G. (2003). Development of the key behaviors change inventory: A traumatic brain injury behavioral outcome assessment instrument. *Archives of Physical Medicine and Rehabilitation, 84*, 277–284.

Kramer, C. Y. (1956). Extension of multiple range tests to group means with unequal numbers of replications. *Biometrics*, *12*(3), 307-310.

Kurths, J., Voss, A., Saparin, P., Witt, A., Kleiner, H. J., & Wessel, N. (1995). Quantitative analysis of heart rate variability. *Chaos: An Interdisciplinary Journal of Nonlinear Science*, *5*(1), 88-94.

Langlois, J. A., Rutland-Brown, W., & Wald, M. M. (2006). The Epidemiology and impact of traumatic brain injury—a brief overview. *Journal of Head Trauma Rehabilitation, 21(5*), 375–378.

Lazarus, R. S., Speisman, J. C., & Mordkoff, A. M. (1963). The relationship between autonomic indicators of psychological stress: Heart rate and skin conductance. *Psychosomatic Medicine*, *25*(1), 19-30.

Lemieux, P., Mckelvie, S. J., & Stout, D. (2002). Self-reported hostile aggression in contact athletes, no contact athletes, and non- athletes. *Psychology*, *4*(3), 42–56.

Ling, J. M., Pena, A., Yeo, R. A., Merideth, F. L., Klimaj, S., Gasparovic, C., & Mayer, A. R. (2012). Biomarkers of increased diffusion anisotropy in semi-acute mild traumatic brain injury: a longitudinal perspective. *Brain, 135*(4), 1281–1292. doi:10.1093/brain/aws073

Lenzi, A., Bianco, I., Milazzo, V., Placidi, G. F., Castrogiovanni, P., & Becherini, D. (1997). Comparison of aggressive behavior between men and women in sport. *Perceptual and Motor Skills*, *84*(1), 139-145.

Levin, H., Li, X., McCauley, S. R., Hanten, G., Wilde, E.A., & Swank, P. R. (2012). Neuropsychological outcome of mTBI: A principal component analysis approach. *Journal of Neurotrauma, 30*(8), 625-632. doi:10.1089/ neu.2012.2627

Macpherson, A., Rothman, L., & Howard, A. (2006). Body-checking rules and childhood injuries in ice hockey. *Pediatrics*, *117*(2), 143-147. doi:10.1542/peds.2005-1163

Marquez de la Plata, C. D. M., Garces, J., Kojori, E. S., Grinnan, J., Krishnan, K., Pidikiti, R., ... & Diaz-Arrastia, R. (2011). Deficits in functional connectivity of hippocampal and frontal lobe circuits after traumatic axonal injury. *Archives of Neurology, 68*(1), 74-84. doi:10.1001/archneurol.2010.342

Marshall, C. (2012). Sports-related concussion: A narrative review of the literature. *Journal of the Canadian Chiropractic Association, 56*(4), 299-310.

Mateer, C. A. (1999). The rehabilitation of executive disorders. In *Cognitive Neurorehabilitation*, 314-332. Cambridge University Press.

Mathias, C. W. & Stanford, M. S. (2003). Impulsiveness and arousal: Heart rate under conditions of rest and challenge in healthy males. *Personality and Individual Differences*, *35*(2), 355-371.

Max, J. E., Robertson, B. A., & Lansing, A. E. (2001). The phenomenology of personality change due to traumatic brain injury in children and adolescents. *Journal of Neuropsychiatry and Clinical Neuroscience, 13*, 161-170.

McAllister, T. W. (2008). Neurobehavioral sequelae of traumatic brain injury: Evaluation and management. *World Psychiatry*, *7*(1), 3-10.

McAllister, T. W., Ford, J. C., Ji, S., Beckwith, J. G., Flashman, L. A, Paulsen, K., & Greenwald, R. M. (2012). Maximum principal strain and strain rate associated with concussion diagnosis correlates with changes in corpus callosum white matter indices. *Annals of Biomedical Engineering*, *40*(1), 127–140. doi:10.1007/s10439-011-0402-6

McCrea, M. (2008). *Mild traumatic brain injury and postconcussion syndrome: The new evidence base for diagnosis and treatment*. Oxford University Press: New York.

McCrea, M., Guskiewicz, K. M., Marshall, S. W., Barr, W., Randolph, C., Cantu, R. C., … Kelly, J. P. (2003). Acute effects and recovery time following concussion in collegiate football players. British Journal of Sports Medicine, 38, 369-371.

McCrea, M., Hammeke, T., Olsen, G., Leo, P., & Guskiewicz, K. (2004). Un-reported concussion in high school football players: Implications for prevention. Clinical *Journal of Sport Medicine,14(1),*13–17.

McCrea, M., Iverson, G. L., McAllister, T. W., Hammeke, T. A., Powell, M. R., Barr, W. B., & Kelly, J. P. (2009). An integrated review of recovery after mild traumatic brain injury (MTBI): Implications for clinical management. *The Clinical Neuropsychologist*, *23*(8), 1368–90. doi:10.1080/13854040903074652

McCrory, P., Johnston, K., Meeuwisse, W., Aubry, M., Cantu, R., Dvorak, J., ... & Schamasch, P. (2005). Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *British Journal of Sports Medicine*, *39*(4), 196-204.

McCrory, P., Meeuwisse, W., Johnston, K., Dvorak, J., Aubry, M., Molloy, M., & Cantu, R. (2009). Consensus Statement on Concussion in Sport – the 3rd International Conference on Concussion in Sport held in Zurich, November 2008, *21*(2), 36–46.

McHugh, L. & Wood, R. L. (2008). Using a temporal discounting paradigm to measure decision-making and impulsivity following traumatic brain injury: A pilot study. *Brain Injury*, *22*(9), 715-721. doi:10.1080/02699050802263027

McKee, A. C., Cantu, R. C., Nowinski, C. J., Hedley-Whyte, E. T., Gavett, B. E., Budson, A. E.,…, & Stern, R. A. (2009). Chronic traumatic encephalopathy in athletes: Progressive tauopathy following repetitive head injury. *Journal Neuropathology of Experimental Neurology, 68*(7), 709-735. doi: 10.1097/NEN.0b013e3181a9d503

McLeod, T. C. V. & Leach, C. (2012). Psychometric properties of self-report concussion scales and checklists. *Journal of Athletic Training*, *47*(2), 221–3.

Meehan, W. P. & Bachur, R. G. (2009). Sport-related concussion. *Pediatrics*, *123*(1), 114–23. doi:10.1542/peds.2008-0309

Meehan, W. P. & Mannix, R. (2010). Pediatric concussions in United States emergency departments in the years 2002 to 2006. *The Journal of Pediatrics, 157*(6), 899-893.doi:10.1016/j.jpeds.2010.06.040

Meehan, W. P., Mannix, R. C., O'Brien, M. J., & Collins, M. W. (2013). The prevalence of undiagnosed concussions in athletes. *Clinical Journal Of Sport Medicine*, *23*(5), 339–342. doi:10.1097/JSM.0b013e318291d3b3

Mendez, M. F., Owens, E. M., Jimenez, E. E., Peppers, D., & Licht, E. (2013). Changes in personality after mild traumatic brain injury from primary blast vs. blunt forces. *Brain Injury*, *27*(1), 10–18. doi:10.3109/02699052.2012.722252

Morales, D., Diaz-Daza, O., Hlatky, R, & Hayman, L. A. (2007). Brain, contusion. Retrieved from http://emedicine.medscape.comlartic1e/337782- overview.

NEPSY -Second Edition (2007). San Antonio, Texas: Harcourt Assessment.

Noble, J. M. & Hesdorffer, D. C. (2013). Sport-related concussions: A review of epidemiology, challenges in diagnosis, and potential risk factors. *Neuropsychology Review*, *23*(4), 273–84. doi:10.1007/s11065-013-9239-0

O’Brien, K. S., Kolt, G. S., Martens, M. P., Ruffman, T., Miller, P. G., & Lynott, D. (2012). Alcohol-related aggression and antisocial behaviour in sportspeople/athletes. *Journal of Science and Medicine in Sport*, *15*(4), 292–297. doi:10.1016/j.jsams.2011.10.008

Olson-Madden, J. H., Brenner, L. A, Corrigan, J. D., Emrick, C. D., & Britton, P. C. (2012). Substance use and mild traumatic brain injury risk reduction and prevention: A novel model for treatment. *Rehabilitation Research and Practice*, 174579. doi:10.1155/2012/174579

Omaron Healthcare Inc. Bannockbum, Illinois.

Oquendo, M. A., Friedman, J. H., Grunebaum, M. F., Burke, A., Silver, J. M., & Mann, J. J. (2004). Suicidal behavior and mild traumatic brain injury in major depression. *Journal of Nervous and Mental Disease, 192*, 430-434.

Ozen, L. J., Itier, R. J., Preston, F. F., & Fernandes, M. A. (2013). Long-term working memory deficits after concussion: Electrophysiological evidence. *Brain Injury*, *27*(11), 1244–1255. doi:10.3109/02699052.2013.804207

Parker, R. S. (1996). The spectrum of emotional distress and personality changes after minor head injury incurred in a motor vehicle accident. *Brain injury*, *10*(4), 287–302.

Patton, J. H. & Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt Impulsiveness Scale. *Journal of Clinical Psychology*, *51*(6), 768-774.

Polygraph Professional. Polygraph Professional Suite. Odessa, ON: Limestone Technologies, Inc.; 2008.

Ponsford, J., Cameron, P., Fitzgerald, M., Grant, M., & Mikocka-Walus, A. (2011). Long-term outcomes after uncomplicated mild traumatic brain injury: A comparison with trauma controls. *Journal of Neurotrauma*, *28*(6), 937–46. doi:10.1089/neu.2010.1516

Ponsford, J. L., Downing, M. G., Olver, J., Ponsford, M., Acher, R., Carty, M., & Spitz, G. (2014). Longitudinal follow-up of patients with traumatic brain injury: Outcome at two, five, and ten years post-injury. *Journal of Neurorauma, 31*(1), 64-77. doi:10.1089/neu.2013.2997

Ponsford, J., Willmott, C., Rothwell, A., Cameron, P., Kelly, A., Nelms, R., Curran, C., & Ng, K. (2000). Factors influencing outcome following mild traumatic brain injury in adults. *Journal of the International Neuropsychological Society, 6,* 568–579.

Potgieter, J., & Bisschoff, F. (1990). Sensation seeking among medium- and low-risk sports participants. *Perceptual and Motor Skills*, *71*(3), 1203–1206. doi:10.2466/pms.1990.71.3f.1203

Prigatano, G. P. (1999). *Principles of neuropsychological rehabilitation*. Oxford University Press: New York.

Rabinowitz, A. R., Li, X., & Levin, H. S. (2014). Sport and nonsport etiologies of mild traumatic brain injury: Similarities and differences. *Annual Review of Psychology*, *65*, 301–31. doi:10.1146/annurev-psych-010213-115103

Rahimizadeh, M., Arabnarmi, B., Mizany, M., Shahbazi, M., & Bidgoli, Z. K. (2011). Determining the difference of aggression in male & female, athlete and non-athlete students. *Procedia - Social and Behavioral Sciences*, *30*, 2264–2267. doi:10.1016/j.sbspro.2011.10.442

Register-Mihalik, J. K., Guskiewicz, K. M., Mihalik, J. P., Schmidt, J. D., Kerr, Z. Y., & McCrea, M. A. (2012). Reliable change, sensitivity, and specificity of a multidimensional concussion assessment battery. *Journal of Head Trauma Rehabilitation*, *28*(4), 274-283. doi:10.1097/HTR.0b013e3182585d37

Reza, A. B. (2012). Comparing the incidence of aggression among student athletes in various sports disciplines at the University of Tiran. *Procedia - Social and Behavioral Sciences*, *47*, 1869–1873. doi:10.1016/j.sbspro.2012.06.915

Rochat, L., Beni, C., Billieux, J., Azouvi, P., Annoni, J. M., & Van der Linden, M. (2010). Assessment of impulsivity after moderate to severe traumatic brain injury. *Neuropsychological Rehabilitation*, *20*(5), 778–97. doi:10.1080/09602011.2010.495245

Rohling, M. L., Binder, L. M., Demakis, G. J., Larrabee, G. J., Ploetz, D. M., & Langhinrichsen-Rohling, J. (2011). A meta-analysis of neuropsychological outcome after mild traumatic brain injury: Re-analyses and reconsiderations of Binder et al. (1997), Frencham et al. (2005), and Pertab et al. (2009). *The Clinical Neuropsychologist*, *25*(4), 608–23. doi:10.1080/13854046.2011.565076

Rowland, G. L., Franken, R. E., & Harrison, K. (1986). Sensation seeking and participation in sporting activities. *Journal of Sport Psychology*, *8*(3), 212–220.

Ryan, L. M. & Warden, D. L. (2003). Post concussion syndrome. *International Review of Psychiatry, 15*(4), 310–316. doi:10.1080/09540260310001606692

Ruff, R. M. (2011). Mild traumatic brain injury and neural recovery: Rethinking the debate. *NeuroRehabilitation, 28*(3), 167–180. doi:10. 3233/NRE-2011-0646

Rutter, M. (1984). *Developmental neuropsychiatry*. Churchill Livingstone, Edinburgh; Melbourne; New York.

Ryu, W. H. A., Feinstein, A., Colantonio, A., Streiner, D. L., & Dawson, D. R. (2009). Early identification and incidence of mild TBI in Ontario. *The Canadian Journal of Neurological Sciences*, *36*(4), 429-435.

Satz P. (2001). Mild head injury in children and adolescents. *Current Directions in Psychological Science,10,* 106–109.

Schmahmann, J. D., Pandya, D. N., Wang, R., Dai, G., D'Arceuil, H. E., de Crespigny, A. J., & Wedeen, V. J. (2007). Association fibre pathways of the brain: Parallel observations from diffusion spectrum imaging and autoradiography. *Brain*, *130*(3), 630-653. doi:http://dx.doi.org/10.1093/brain/awl359

Segalowitz, S. J. & Lawson, S. (1995). Subtle symptoms associated with self-reported mild head injury. *Journal of Learning Disabilities, 28*(5), 309-319.

Sela-Kaufman, M., Rassovsky, Y., Agranov, E., Levi, Y., & Vakil, E. (2013). Premorbid personality characteristics and attachment style moderate the effect of injury severity on occupational outcome in traumatic brain injury: Another aspect of reserve. *Journal of Clinical And Experimental Neuropsychology*, *35*(6), 584–95. doi:10.1080/13803395.2013.799123

Slobounov, S., Gay, M., Johnson, B., & Zhang, K. (2012). Concussion in athletics: Ongoing clinical and brain imaging research controversies. *Brain Imaging and Behavior*, *6*(2), 224–43. doi:10.1007/s11682-012-9167-2

Smith, A. (1982). Symbol Digits Modalities Test. Western Psychological Services: Los Angeles.

Smither, R. D. & Houston, J. M. (1992). The nature of competitiveness: Construction and validation of the Competitiveness Index. *Educational and Psychological Measurement,* 52, 407-418.

Sønderlund, A. L., O'Brien, K., Kremer, P., Rowland, B., De Groot, F., Staiger, P., … Miller, P. G. (2014). The association between sports participation, alcohol use and aggression and violence: A systematic review. *Journal of Science and Medicine in Sport*, *17*(1), 2–7. doi:10.1016/j.jsams.2013.03.011

Sosin, D. M., Sniezek, J. E., & Thurman, D. J. (1996). Incidence of mild and moderate brain injury in the United States, 1991. *Brain injury*, *10*(1), 47-54.

Spear, J. (1995). Are footballers at risk for developing dementia? *International Journal of Geriatric Psychiatry, 10,* 1011–1014.

Stern Y. (2009). Cognitive reserve. *Neuropsychologia, 47*, 2015–2028.

Suhr, J. A., & Gunstad, J. (2002). "Diagnosis threat": The effect of negative expectations on cognitive performance in head injury. *Journal of Clinical & Experimental Neuropsychology, 24(4)*, 448.

Suhr, J., & Gunstad, J. (2005). Further exploration of the effect of diagnosis threat on cognitive performance in individuals with mild head injury. *Journal of the International Neuropsychological Society, 11(1)*, 23-29.

Stambrook, M., Moore, A. D., Peters, L. C., Deviaene, C., & Hawryluk, G. (1990). Effects of mild, moderate and severe closed head injury on long-term vocational status. *Brain Injury*, *4*(2), 183–90.

Starcevic, V., Uhlenhuth, E. H., Fallon, S., & Pathak, D. (1996). Personality dimensions in panic disorder and generalized anxiety disorder. *Journal Of Affective Disorders*, *37*(2), 75-79.

Strain, J. F., Womack, K. B., Didehbani, N., Spence, J. S., Conover, H., Hart, J., … Cullum, C. M. (2015). Imaging correlates of memory and concussion history in retired National Football League athletes. *JAMA Neurology*, *9044*, 1–8. doi:10.1001/jamaneurol.2015.0206

Sztajzel, J. (2004). Heart rate variability: A noninvasive electrocardiographic method to measure the autonomic nervous system. *Swiss Medical Weekly*,*134*, 514-522.

Tateno, A., Jorge, R. E., & Robinson, R. G. (2003). Clinical correlates of aggressive behavior after traumatic brain injury. *Journal of Neuropsychiatry and Clinical Neuroscience, 15*, 155-160.

Teasdale, G. & Jennett, B. (1974). Assessment of coma and impaired consciousness: A practical scale. *The Lancet*, *304*(7872), 81-84.

Thompson, N. J. & Morris, R. D. (1994). Predicting injury risk in adolescent football players: The importance of psychological variables. *Journal of Pediatric Psychology*, *19*(4), 415-429.

Tommasone, B. A. & Valovich McLeod, T. C. (2006). Contact sport concussion incidence. *Journal of athletic training*, *41*(4), 470–472.

Torkelson, R. M. & Jellinek, H. M., Malec, J. F., & Harvey, R. F. (1983). Traumatic brain injury: Psychological and medical factors related to rehabilitation outcome. *Rehabilitation Psychology, 28*, 169-176. doi:10.1037/h0090992

Tucker, L. W. & Parks, J. B. (2001). Effects of gender and sport type on intercollegiate athletes' perceptions of the legitimacy of aggressive behaviors in sport. *Sociology of Sport Journal*, *18*(4), 403-413.

Tyson, P. D. (1998). Physiological arousal, reactive aggression, and the induction of an incompatible relaxation response. *Aggression and Violent Behavior*, *3*(2), 143-158.

Umile, E. M., Sandel, M. E., Alavi, A., Terry, C. M., & Plotkin, R. C. (2002). Dynamic imaging in mild traumatic brain injury: support for the theory of medial temporal vulnerability. *Archives of Physical Medicine and Rehabilitation*, *83*(11), 1506-1513.

Vagnozzi, R., Signoretti, S., Tavazzi, B., Floris, R., Ludovici, A., Marziali, S., ... & Lazzarino, G. (2008). Temporal window of metabolic brain vulnerability to concussion: A pilot 1H-magnetic resonance spectroscopic study in concussed athletes-part III. *Neurosurgery*, *62*(6), 1286-1296. doi:10.1227/01.NEU.0000316421.58568.AD

Valovich McLeod, T. C., Bay, R. C., Lam, K. C., & Chhabra, A. (2012). Representative baseline values on the Sport Concussion Assessment Tool 2 (SCAT2) in adolescent athletes vary by gender, grade, and concussion history. *The American Journal of Sports Medicine*, *40*(4), 927–933. doi:10.1177/0363546511431573

van Noordt, S. & Good, D. (2011). Mild head injury and sympathetic arousal: Investigating relationships with decision-making and neuropsychological performance in university students. *Brain Injury*, *25*(7-8), 707-716.

Votruba, K. L., Rapport, L. J., Vangel Jr, S. J., Hanks, R. A., Lequerica, A., Whitman, R. D., & Langenecker, S. (2008). Impulsivity and traumatic brain injury: The relations among behavioral observation, performance measures, and rating scales. *The Journal of Head Trauma Rehabilitation*, *23*(2), 65-73. doi:10.1097/01.HTR.0000314525.93381.69

Wallis, J. D. (2007). Orbitofrontal cortex and its contribution to decision-making. *Annual Review of Neuroscience, 30*, 31-56. doi:10.1146/annurev.neuro.30.051606.094334

Wechsler, D. (1981). WAIS-R manual: Wechsler Adult Intelligence Scale-Revised. New York: Psychological Corporation.

Wechsler D. (1997). Wechsler Adult Intelligence Scale-III. New York: Psychological Corporation.

Whiteside, S. P. & Lynam, D. R. (2001). The Five Factor Model and Impulsivity: Using a structural model of personality to understand impulsivity. *Personality and Individual Differences, 30*, 669–689.

Wilkinson, G. S. & Robertson, G. J. (2006). *Wide Range Achievement Test IV Professional Manual*. Lutz, FL: Psychological Assessment Resources.

Williams, M., Rapport, L., Hanks, R., Millis, S., & Greene, A. (2013). Incremental validity of neuropsychological evaluations to computed tomography in predicting long-term outcomes after traumatic brain injury. *The Clinical Neuropsychologist, 27*, 356-375.

Wong T. M. (2011). Brain injury and aggression – Can we get some help? *Neurology, 76,*1032–1033.

Wood, R. L. (2001). Understanding neurobehavioural disability. *Neurobehavioural Disability And Social Handicap Following Traumatic Brain Injury*, 3-27.

Yerkes, R. & Dodson, J. (1908). The relation of stimulus strength to rapidity of habit formation. *Journal of Comparative Neurological Psychology*, *18*, 459-482.

Zakzanis, K., Leach, L., & Kaplan, E. (1998). On the nature and pattern of neurocognitive function in major depressive disorder. *Cognitive and Behavioral Neurology*, *11*(3), 111-119.

Zhang L., Yang K. H., & King A.I. (2004). A proposed injury threshold for mild traumatic brain injury. *Journal of Biomechanical Engineering, 126(2),* 226–36.

Ziaee, V., Lotfian, S., Amini, H., Mansournia, M. A., & Memari, A. H. (2012). Anger in adolescent boy athletes: A comparison among judo, karate, swimming and non athletes. *Iranian Journal of Pediatrics*, *22*(1), 9–14.

Zuckerman, M. (1983). Sensation seeking and sports. *Personality and Individual Differences*, *4*(3), 285-292.

Zuckerman, S. L., Lee, Y. M., Odom, M. J., Solomon, G. S., Forbes, J. A., & Sills, A. K. (2012). Recovery from sports-related concussion: Days to return to neurocognitive baseline in adolescents versus young adults. *Surgical Neurology International*, *3*, 130. doi:10.4103/2152-7806.102945

Appendix A

Data Collection and Testing Materials

Appendix A Table of Contents

PARTICIPANTS NEEDED!!!

FOR A RESEARCH STUDY INVESTIGATING

INDIVIDUAL DIFFERENCES BETWEEN

ATHLETES AND NON-ATHLETES

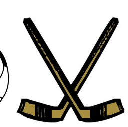
Participation will include:

- Roughly two hours of questionnaires, cognitive tasks, saliva samples, and physiological measures such as heart rate, blood pressure, skin conductance, and respiration
- Must be between the ages of 17-30
- You are eligible to receive **RESEARCH PARTICIPATION HOURS OR A $20 GIFT CARD**

If you would like more information or would like to participate, please contact **Nicole** at:
nb13gc@brocku.ca
OR
(905) 688-5550 ext. 3034

Nicole Barry (M.A. Candidate)
Psychology Department
Supervisor: Dr. Dawn Good
Dawn.Good@brocku.ca



Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Call ext. 3034 for Nicole Barr
E-mail: nb13gc@brocku.ca

Participant Consent Form

Individual Differences Between Athletes and Non-athletes

Nicole Barry, B.Sc, M.A. Candidate & Dr. Dawn Good, C. Psych,

Psychology Department, Brock University

In this study, we will be examining individual differences between athletes and non-athletes. The study is divided into two parts: today you will complete the first half of data collection and approximately four to six months from now (or when a specific sport season ends) you will asked to return for the second. The first and second parts will be very similar. You will be asked to complete a package of questionnaires related to demographics (sex, age, medical history, etc.), and personality. Some questions may be personal or sensitive in nature, and you may choose to omit any question you prefer not to answer. This study will also include non-invasive physiological measures (heart rate, skin conductance [sweat response], blood pressure, respiration, and saliva collection). You will assist the researcher in placing two electrodes on your fingers for skin conductance, a pulse oximeter on your thumb to measure heart rate, a blood pressure cuff on your upper arm, and respiration bands on your abdomen and chest. The researcher will wear gloves at this time. You will also be asked to provide saliva samples by drooling passively into a test tube to look for differences in specific hormones. The samples will be frozen and kept in a secure location until they are analyzed. The Principal Researchers and members of the Developmental Neuroendocrinology lab at Brock will have access to these samples. No personal identifiers will be associated with the samples. Saliva will be disposed of immediately after analyses. Finally, you are asked to complete various neuropsychological measures; these tasks involve cognitive tasks including the answering of questions, drawing, and reading. Detailed instructions will be provided to you throughout the testing session. In total, the testing in this study will take approximately two hours to complete at each session.

Your participation is completely voluntary. You may withdraw from this study at any time without penalty.

All information obtained in this study will be kept strictly confidential. All data will be coded with an alphanumeric code so that no data will have your personal identification associated with it. However, there will be a Master list advising the Principal Researchers (Dr. Dawn Good, Nicole Barry, MA candidate) of each participants' identity so that we can correctly match your data across the two test sessions and multiple sources of collection (i.e., computer collected physiological measures, paper-based task performance). This restricted access list will be held in a separate, secure and locked location. Further, the results of the study will be presented in a statistical format and as a group - no individual participant information will be published or identified. The information you provide (your data, answers, with only an alphanumeric code identifier) will be kept locked in a secure location for five years, to which only researchers and research assistants have access. Data will be subsequently destroyed. If you choose to withdraw from the study prior to completion, your data will not be used in the analyses and will be destroyed. The researcher will only use data for research purposes. Further, the information/data you provide will not be accessible or given to any other resource (e.g., sports league, health professional) without your explicit request and consent (in this event an additional consent form that is consistent with the guidelines of PHIPA [2004] for release of information would be required and signed by you).

You will receive a detailed debriefing form about the study at the end of testing. You may receive course credit or monetary compensation for your participation. Also, you may contact the researchers via e-mail if you wish to view the results of the study.

Potential benefits of participating in the study include learning about a longitudinal research study, personality, and about brain and behaviour relationships.

A potential risk of the current study is that you may also feel psychological risk in completing neuropsychological measures. However, the tests do not reflect your intellectual capacity and are intentionally challenging. Individual statistics and scores will not be included in any analyses. You will be provided with counseling information at the end of the testing session. Again, you may choose to withdraw from the study at any time.

If you have any questions about this study or require further information, please contact us using the information provided below.
Contact at (905) 688-5550 ext. 3034
Nicole Barry: nb13gc@brocku.ca
Dr. Dawn Good: Dawn.Good@brocku.ca
I have read the information presented about the current study being conducted by Dr. Dawn Good and Nicole Barry investigating individual differences between athletes and non-athletes in the Psychology Department at Brock University.

[ ] I have read and understand the above information regarding this study.

[ ] I have received a copy of this form.

[ ] I understand that I may ask questions at any time during the study and in the future.

[ ] I understand that I may withdraw from this study at any time.

[ ] I agree to participate in this study.

[ ] I give permission to be contacted regarding this study or future studies.

[ ] I give permission for athletic staff to disclose any injuries I sustained over the season. [ ] N/A

Participant's signature: ____

Date: ____________________________________

Compensation:

[ ] COURSE to receive up to two research credits (two hours; 0.5 every 30 minutes)

[ ] $20.00 Cineplex Odeon gift card (or $5.00 every 30 minutes)

To be completed by researcher:

[ ] I have explained this study to the participant

Researcher's signature: ____

Date: _____________________________________

THANK YOU FOR YOUR PARTICIPATION!

This project has been reviewed and received ethics clearance through the Office of Research Ethics Board #13-310. If you have any pertinent questions regarding your rights as a participant, please contact the Research Ethics Officer via e-mail at reb@brocku.ca or you may call (905) 688-5550 extension 3035.

Contact Information/Counseling Services

Individual Differences Between Athletes and Non-athletes

Nicole Barry & Dr. Dawn Good

Neuropsychology Cognitive Research Laboratory, Psychology Department, Brock University

Thank-you for completing part I of our two-part study regarding individual differences between athletes and non-athletes. If you had any negative experiences (e.g., reading/responding to sensitive questions, increased cognitive demands) as a result of participating in this research study and wish to speak with a counsellor please contact: **Brock University Counselling Services, Schmon Tower 400, (905) 688-5550 extension 4750,** http://www.brocku.ca/personal-counselling or the Principal Investigator, Dr. Dawn Good, Department of Psychology, B308 MC, extension 3869, dawn.good@brocku.ca**.** Your performance, responses, experience and concerns will remain confidential. Should there be any health-related concerns or responses that require further addressing, the Principal Investigator will contact you directly and advise you of such, while respecting confidentiality and privacy as dictated by the *Personal Health Information Protection Act*, PHIPPA, legislation (e.g., http://www.elaws.gov.on.ca/html/statutes/english/elaws_statutes_04p03_e.htm).

Thank-you again! If you have any questions or concerns regarding the study or procedures for Part II of the study, please feel free to contact us at the e-mails provided below, or through the Department of Psychology. Otherwise, we will be in touch with you in a few months to arrange for further testing and follow up.

Nicole Barry: nb13gc@brocku.ca Dr. Dawn Good: Dawn.Good@brocku.ca

This project has been reviewed and received ethics clearance through the Office of Research Ethics Board #13-310. If you have any pertinent questions regarding your rights as a participant, or feel your rights have been violated, please contact the Research Ethics Officer via e-mail at reb@brocku.ca or you may call (905) 688-5550 extension 3035.

Participant Debriefing Form

Individual Differences Between Athletes and Non-athletes

Nicole Barry & Dr. Dawn Good

Neuropsychology Cognitive Research Laboratory, Psychology Department, Brock University

Thank-you for participating in this study. The purpose of this research is to investigate the effects of concussion, particularly sports-related concussion, and the potential individual differences variables that may influence the outcome after an injury. Athletes, especially in high-impact sports, are at risk of sustaining concussion(s). Approximately 25 to 45 percent of university students have sustained a concussion via athletics or other activities. Many cognitive, affective (emotional), behavioural, and physiological deficits have been reported and observed in individuals after sustaining a brain injury. However, there is less research regarding the effects of mild injuries to the head and very little research investigating the individual differences that may influence outcome after mild head injuries. Neural changes after concussions are mostly temporary (i.e., resolve fully within three weeks) and, otherwise, subtle but can occasionally have more persistent effects lasting longer than three months. It is our intention to understand the implications that concussion may have on function (emotional, cognitive), if any, and ultimately, optimize functioning for any person with impact injuries to the head. We are also attempting to determine whether there are particular characteristics (e.g., the type of sport someone plays, personality traits, physiological indices) that may be associated with the occurrence or trajectory of concussion (e.g., increase susceptibility to sustaining a concussion). Furthermore, we expect that there will be differences in testosterone levels (which we collected via saliva samples) between individuals who have experienced a head injury and those who have not and athletes and non-athletes. Therefore, it was important that we tested participants in a test-retest design. The results of this study could have important implications for the sports community regarding return-to-play guidelines as well as contributing important knowledge to the brain-behaviour/concussion research literature.

To ensure anonymity and privacy, individual names are not associated with data collected in this study; with exception of a master list to which only the Principal Researchers have access. As a result, individual results cannot be provided. All data will be summarized and presented as a group in a thesis project, in publishable journals, and at conferences. You are invited to view the results at the time of completion in August 2015. Should there be any need or request for health related (but not experimental) data to be released to another Regulated Health Professional or person of your preference, a "Consent to Release Personal Information" form would be required and need to be explicitly requested by you.

If you had any negative experiences (e.g., reading/responding to sensitive questions, increased cognitive demands) as a result of participating in this research study and wish to speak with a counsellor please contact: Brock University Counselling Services, Schmon Tower 400, (905) 688-5550 extension 4750, http://www.brocku.ca/personal-counselling or the Principal Investigator, Dr. Dawn Good, Department of Psychology, B308 MC, extension 3869, dawn.good@brocku.ca**.** Your performance, responses, experience and concerns will remain confidential. Should there be any health-related concerns or responses that require further addressing, the Principal Investigator will contact you directly and advise you of such, while respecting confidentiality and privacy as dictated by the *Personal Health Information Protection Act*, PHIPPA, legislation (e.g., http://www.elaws.gov.on.ca/html/statutes/english/elaws_statutes_04p03_e.htm). If you would like more information/ support regarding head trauma, please consider the following resources: The Ontario Brain Injury Association (OBIA): www.obia.ca; The Ontario Neurotrauma Foundation (ONF): www.onf.org; Brain Injury Association of Niagara (BIAN): *www.**bianiagara**.org*.

Thank-you again! If you have any questions or concerns please feel free to contact:

Nicole Barry: nb13gc@brocku.ca, (905) 688-5550, x 3034
Dr. Dawn Good: Dawn.Good@brocku.ca, (905) 688-5550, x 3869
Or the Department of Psychology, (905) 688-5550, x 5050

This project has been reviewed and received ethics clearance through the Office of Research Ethics Board #13-310. If you have any pertinent questions regarding your rights as a participant, or feel your rights have been violated, please contact the Research Ethics Officer via e-mail at reb@brocku.ca or you may call (905) 688-5550 extension 3035.

UPPS-P

Below are a number of statements that describe ways in which people act and think. For each statement, please indicate how much you agree or disagree with the statement. If you **Agree Strongly** circle **1**, if you **Agree Somewhat** circle **2**, if you **Disagree somewhat** circle **3**, and if you **Disagree Strongly** circle **4**. Be sure to indicate your agreement or disagreement for every statement below. Also, there are questions on the following pages.

Agree Agree Disagree Disagree
Strongly Some Some
Strongly

1. I have a reserved and cautious attitude toward life.	1	2	3	4
2. I have trouble controlling my impulses.	1	2	3	4
3. I generally seek new and exciting experiences and sensations.	1	2	3	4
4. I generally like to see things through to the end.	1	2	3	4
5. When I am very happy, I can't seem to stop myself from doing things that can have bad consequences.	1	2	3	4
6. My thinking is usually careful and purposeful.	1	2	3	4
7. I have trouble resisting my cravings (for food, cigarettes, etc.).	1	2	3	4
8. I'll try anything once.	1	2	3	4
9. I tend to give up easily.	1	2	3	4
10. When I am in great mood, I tend to get into situations that could cause me problems.	1	2	3	4
11. I am not one of those people who blurt out things without thinking.	1	2	3	4
12. I often get involved in things I later wish I could get out of.	1	2	3	4
13. I like sports and games in which you have to choose your next move very quickly.	1	2	3	4
14. Unfinished tasks really bother me.	1	2	3	4
15. When I am very happy, I tend to do things that may cause problems in my life.				
16. I like to stop and think things over before I do them.	1	2	3	4
17. When I feel bad, I will often do things I later regret in order to make myself feel better now.	1	2	3	4
18. I would enjoy water skiing.	1	2	3	4
19. Once I get going on something I hate to stop.	1	2	3	4
20. I tend to lose control when I am in a great mood.	1	2	3	4
21. I don't like to start a project until I know exactly how to proceed.	1	2	3	4
	1	2	3	4

	Agree Strongly	Agree Some	Disagree Some	Disagree Strongly
22. Sometimes when I feel bad, I can’t seem to stop what I am doing even though it is making me feel worse.	1	2	3	4
23. I quite enjoy taking risks.	1	2	3	4
24. I concentrate easily.	1	2	3	4
25. When I am really ecstatic, I tend to get out of control.	1	2	3	4
26. I would enjoy parachute jumping.	1	2	3	4
27. I finish what I start.	1	2	3	4
28. I tend to value and follow a rational, "sensible" approach to things.	1	2	3	4
29. When I am upset I often act without thinking.	1	2	3	4
30. Others would say I make bad choices when I am extremely happy about something.	1	2	3	4
31. I welcome new and exciting experiences and sensations, even if they are a little frightening and unconventional.	1	2	3	4
32. I am able to pace myself so as to get things done on time.	1	2	3	4
33. I usually make up my mind through careful reasoning.	1	2	3	4
34. When I feel rejected, I will often say things that I later regret.	1	2	3	4
35. Others are shocked or worried about the things I do when I am feeling very excited.	1	2	3	4
36. I would like to learn to fly an airplane.	1	2	3	4
37. I am a person who always gets the job done.	1	2	3	4
38. I am a cautious person.	1	2	3	4
39. It is hard for me to resist acting on my feelings.	1	2	3	4
40. When I get really happy about something, I tend to do things that can have bad consequences.	1	2	3	4
41. I sometimes like doing things that are a bit frightening.	1	2	3	4
42. I almost always finish projects that I start.	1	2	3	4
43. Before I get into a new situation I like to find out what to expect from it.	1	2	3	4
44. I often make matters worse because I act without thinking when I am upset.				
45. When overjoyed, I feel like I can’t stop myself from going overboard.	1	2	3	4
	1	2	3	4

Please go to the next page

	Agree Strongly	Agree Some	Disagree Some	Disagree Strongly
46. I would enjoy the sensation of skiing very fast down a high mountain slope.				
47. Sometimes there are so many little things to be done that I just ignore them all.	1	2	3	4
48. I usually think carefully before doing anything.				
49. Before making up my mind, I consider all the advantages and disadvantages.	1	2	3	4
50. When I am really excited, I tend not to think of the consequences of my actions.	1	2	3	4
51. In the heat of an argument, I will often say things that I later regret.				
52. I would like to go scuba diving.	1	2	3	4
53. I tend to act without thinking when I am really excited.				
54. I always keep my feelings under control.	1	2	3	4
55. When I am really happy, I often find myself in situations that I normally	1	2	3	4
wouldn't be comfortable with.	1	2	3	4
56. I would enjoy fast driving.	1	2	3	4
57. When I am very happy, I feel like it is ok to give in to cravings or overindulge.	1	2	3	4
58. Sometimes I do impulsive things that I later regret.				
59. I am surprised at the things I do while in a great mood.	1	2	3	4
	1	2	3	4
	1	2	3	4
	1	2	3	4
	1	2	3	4

BPAQ

Using the 5 point scale shown below, indicate how uncharacteristic or characteristic each of the following statements is in describing you.

1	2	3	4	5
Extremely uncharacteristic of me	Somewhat uncharacteristic of me	Neither characteristic nor uncharacteristic of me	Somewhat characteristic of me	Extremely characteristic of me

1. Some of my friends think I am a hothead.	1	2	3	4	5
2. If I have to resort to violence to protect my rights, I will.	1	2	3	4	5
3. When people are especially nice to me, I wonder what they want.	1	2	3	4	5
4. I tell my friends openly when I disagree with them.	1	2	3	4	5
5. I have become so mad that I have broken things.	1	2	3	4	5
6. I can't help getting into arguments when people disagree with me.	1	2	3	4	5
7. I wonder why sometimes I feel so bitter about things.	1	2	3	4	5
8. Once in a while, I can't control the urge to strike another person.	1	2	3	4	5
9. I am an even-tempered person.	1	2	3	4	5
10. I am suspicious of overly friendly strangers.	1	2	3	4	5
11. I have threatened people I know.	1	2	3	4	5
12. I flare up quickly but get over it quickly.	1	2	3	4	5
13. Given enough provocation, I may hit another person.	1	2	3	4	5
14. When people annoy me, I may tell them what I think of them.	1	2	3	4	5
15. I am sometimes eaten up with jealousy.	1	2	3	4	5
16. I can think of no good reason for ever hitting a person.	1	2	3	4	5
17. At times I feel I have gotten a raw deal out of life.	1	2	3	4	5
18. I have trouble controlling my temper.	1	2	3	4	5
19. When frustrated, I let my irritation show.	1	2	3	4	5
20. I sometimes feel that people are laughing at me behind my back.	1	2	3	4	5
21. I often find myself disagreeing with people.	1	2	3	4	5
22. If somebody hits me, I hit back.	1	2	3	4	5
23. I sometimes feel like a powder keg ready to explode.	1	2	3	4	5
24. Other people always seem to get the breaks.	1	2	3	4	5
25. There are people who pushed me so far that we came to blows.	1	2	3	4	5
26. I know that "friends" talk about me behind my back.	1	2	3	4	5
27. My friends say that I'm somewhat argumentative.	1	2	3	4	5
28. Sometimes I fly off the handle for no good reason.	1	2	3	4	5
29. I get into fights a little more than the average person.	1	2	3	4	5

MC

On a scale from 1 (strongly disagree) to 5 (strongly agree), please answer each statement as it best applies to you.

1. I like competition.
   1 2 3 4 5
   Strongly Disagree Strongly Agree

2. I set goals for myself when I compete.
   1 2 3 4 5
   Strongly Disagree Strongly Agree

3. I am a competitive individual.
   1 2 3 4 5
   Strongly Disagree Strongly Agree

4. Winning is important.
   1 2 3 4 5
   Strongly Disagree Strongly Agree

5. I try to avoid arguments.
   1 2 3 4 5
   Strongly Disagree Strongly Agree

6. I am most competitive when I try to achieve personal goals.
   1 2 3 4 5
   Strongly Disagree Strongly Agree

7. I enjoy competing against an opponent.
   1 2 3 4 5
   Strongly Disagree Strongly Agree

8. Scoring more points than my opponent is very important to me.
   1 2 3 4 5
   Strongly Disagree Strongly Agree

9. I don't like competing with other people.
   1 2 3 4 5
   Strongly Disagree Strongly Agree

10. I try my hardest when I have a specific goal.
    1 2 3 4 5
    Strongly Disagree Strongly Agree

11. I will do almost anything to avoid an argument.
    1 2 3 4 5
    Strongly Disagree Strongly Agree

12. I hate to lose.
    1 2 3 4 5
    Strongly Disagree Strongly Agree

13. I get satisfaction from competing with others.

1	2	3	4	5
Strongly Disagree				Strongly Agree

14. Reaching personal performance goals is very important to me.

1	2	3	4	5
Strongly Disagree				Strongly Agree

15. I find competitive situations unpleasant.

1	2	3	4	5
Strongly Disagree				Strongly Agree

16. The only time I am satisfied is when I win.

1	2	3	4	5
Strongly Disagree				Strongly Agree

17. I often remain quiet rather than risk hurting another person.

1	2	3	4	5
Strongly Disagree				Strongly Agree

18. The best way to determine my ability is to set a goal and try to reach it.

1	2	3	4	5
Strongly Disagree				Strongly Agree

19. I dread competing with other people.

1	2	3	4	5
Strongly Disagree				Strongly Agree

20. Losing upsets me.

1	2	3	4	5
Strongly Disagree				Strongly Agree

21. I don’t enjoy challenging others even when I think they are wrong.

1	2	3	4	5
Strongly Disagree				Strongly Agree

22. Performing to the best of my ability is very important to me.

1	2	3	4	5
Strongly Disagree				Strongly Agree

23. I try to avoid competing with others.

1	2	3	4	5
Strongly Disagree				Strongly Agree

24. I have the most fun when I win.

1	2	3	4	5
Strongly Disagree				Strongly Agree

25. I often try to outperform others.

1	2	3	4	5
Strongly Disagree				Strongly Agree

26. In general, I will go along with the group rather than create conflict.

1	2	3	4	5
Strongly Disagree				Strongly Agree

Everyday Living Questionnaire: Part I

Please fill in or circle an answer for each of the following. If you have any questions regarding clarification please ask the researcher. Thank you for your time and effort!

1. How old are you? ____

2. Gender? M___ F____

3. What is the highest level of education you have presently completed?
    a Less than high school
    b. High School/Grade 12
    c. College 1 2 3 4 4+
    d. University 1 2 3 4 4+ (Years)

4. What is the highest level of education your **mother** has received?
    a Less than high school
    b. High School/Grade 12
    c. College 1 2 3 4 4+
    d. University 1 2 3 4 4+ (Years)
    e. Unsure

5. What is the highest level of education your **father** has received?
    a Less than high school
    b. High School/Grade 12
    c. College 1 2 3 4 4+
    d. University 1 2 3 4 4+ (Years)
    e. Unsure

6. What is the overall average income your parent(s)/guardian(s)?
    a. Under $25,000
    b. $25,000 – $49,999
    c. $50,000 – $74,999
    d. $75,000 - $99,999
    e. $100,000 – $124,999
    f. $125,000 - $149,999
    g. $150,000 or more

7. With which ethnicity do you identify most with:
    a. Hispanic
    b. Caucasian
    c. European
    d. African
    e. Chinese
    f. East Indian
    g. West Indian
    h. Japanese
    i. Other
    Specify: ______________

8. Which faculty is your major affiliated with (e.g., Social Sciences, Humanities, etc.)
    a. Social Sciences
    b. Humanities
    c. Maths and Sciences
    d. Education
    e. Applied Health Sciences
    f. Business

g. Undeclared

9. Which hand is your dominant hand (i.e., are you right or left-handed)?
    a. Right
    b. Left
    c. Both

10. Have you ever been hospitalized for (circle any that apply):
    a. Fractures Y N
    b. Illness Y N
    c. Surgery Y N
    d. Neurological complications Y N
    e. Other Y N

    If you answered Y to any of the above, briefly please provide details:
    e.g., How old were you? How did it happen?
    ____
    ____

11. Have you ever been diagnosed with a neurological condition? Y N

12. Have you ever been diagnosed with a psychiatric condition? Y N

13. Are you currently taking any prescribed medications for a neurological or psychiatric condition? Y N

    a. If yes, if you wish to disclose what medication please do so: ______________________

14. Are you currently taking any prescribed medication for a thyroid condition? Y N
    a. If yes, explain if you feel comfortable: ________________

15. Are you currently taking any oral contraception? Y N N/A

16. Do you take medication for asthma such as an inhaler? Y N

17. Have you ever sustained an injury to your head with a force sufficient to alter your consciousness (e.g. dizziness, vomiting, seeing stars, or loss of consciousness, or confusion)? Y N
    [If you answered **no** to this question you may move ahead to **question 30**]

If yes to question 17, please answer the following questions (if you have had more than one injury, please refer to the *most recent* time you injured your head):

18. If you answered yes to question 14, did you experience these symptoms for more than 20 minutes? Y N

19. Did you experience a loss of consciousness associated with the head injury? Y N

    i. If so, how long was the loss of consciousness?
        1. [ ] < 5 minutes
        2. [ ] < 30 minutes
        3. [ ] < 24 hours
        4. [ ] < 1 week
        5. [ ] < 1 month

6. [ ] > 1 month

20. If applicable, where did you strike your head?
    a. Front of the head
    b. Right side of the head
    c. Left side of the head
    d. Other Provide brief details: ____________________________
    e. I can't remember

21. How did you injure your head?
    i. [ ] Motor vehicle collision
    ii. [ ] Sports-related injury Please specify sport(s): ____
    iii. [ ] Falling
    iv. [ ] Other Please Specify:______________________________

22. Please briefly describe the incident during which the head injury occurred:

____

____

____

23. Please answer the following questions:

    a. Did the head injury result in a concussion? Y N

    b. Did it require stitches? Y N

    c. Did you receive medical treatment for your injury? Y N

    d. Did you stay overnight at a medical care facility? Y N

    e. Approximately how old were you at the time? ___

    f. How many months or year(s) have passed since you hit your head? ___

24. Have you sustained *more than one* injury to your head with a force sufficient to alter your consciousness (e.g., dizziness, vomiting, seeing stars, loss of consciousness, or confusion)? Y N

    a. **If yes**, how many times? ___

    [If you answered **no** to this question you may move ahead to **question 31**]

25. **If you answered yes to question 24**, did you experience these symptoms for more than 20 minutes? Y N

If you responded yes to question 24, please answer the following with respect to your *least recent* head injury:

26. Did you experience a loss of consciousness associated with the least recent head injury? Y N
    a. If so, how long was the loss of consciousness?
        i. [ ] < 5 minutes

ii. [ ] < 30 minutes
iii. [ ] < 24 hours
iv. [ ] < 1 week
v. [ ] < 1 month
vi. [ ] > 1 month

27. If applicable, where did you strike you head?
    a. Front of the head
    b. Back of the head
    c. Right side of the head
    d. Left side of the head
    e. Other Provide brief details: ___________________________
    f. I can't remember

28. How did you injure your head?
    a. [ ] Motor vehicle collision
    b. [ ] Sports-related injury Please specify sport(s):
    ____
    c. [ ] Falling
    d. [ ] Other Please specify:______________________________

29. Please briefly describe the incident during which the least recent head injury occurred:

____

____

____

30. Please answer the following questions:

    a. Did the head injury result in a concussion? Y N

    b. Did it require stitches? Y N

    c. Did you receive medical treatment for your injury? Y N

    d. Did you stay overnight at a medical care facility? Y N

    e. Approximately how old were you at the time? ___

    f. How many months or year(s) have passed since you hit your head? ___

    g. Did the injury result in any litigation processes? Y N

********_**If you were instructed to move ahead to question 31 please begin here**_********

31. Have you ever been involved in a litigation process of any sort? Y N

32. Have you ever experienced any other neural trauma (e.g. stroke, anoxia)? Y N
    a. **If yes**, please explain:
    ____

____

33. Do you smoke cigarettes? Y N

If yes, approximately how many a day? ___

34. Do you regularly engage in consuming alcohol? Y N

a. If yes, how many drinks per week do you consume? __________
b. On average how many drinks would you consume in one outing? __________

35. Do you engage in recreational drug use? Y N
a. Do you smoke marijuana? Y N

If yes to question 35 a., please answer the following. If no, please advance to question 36.

i. How long have you been smoking marijuana (months/years)? ______

ii. In your lifetime, how many instances have you smoked?
1. 0
2. 1-2
3. 2-10
4. 10-30
5. 30-50
6. 5-100
7. 100-300
8. 300+

iii. Please rate your marijuana use in the past 30 days.
1. No use
2. Once or twice
3. Weekly
4. Daily

iv. Have you had symptoms in the past you believe were caused, aggravated, or ameliorated by marijuana smoking? Y N
If yes, please explain: ______________________________

v. Have you had symptoms now you believe were caused or aggravated by marijuana use? Y N
If yes, please explain: ______________________________

vi. What are your general motives for using marijuana? Select all that apply.
1. To deal with anxiety
2. To cope with pain
3. For pleasure
4. Other. Explain: ______________________________

********_**If you were instructed to move ahead to question 36 please begin here**_********

36. Do you take any performance enhancing drugs?

37. Did you consume caffeine today (e.g., coffee, tea, energy drink, chocolate)? Y N

   a. **If yes**, how much?
      1 2 3 more than 3

   b. **If yes**, how much time has past since you last consumed caffeine today?

      Less than 1 hour More than 1 hour

38. Do you have sensitivity to perfumes or scents? Y N
    If yes, please rate your sensitivity:

    Not at all Very
    1 2 3 4 5 6 7 8 9

39. Do you have a valid driver's license? Y N

    a. **If yes**, how long have you had a driver's license? 1-3 years 4-6 years 7+ years N/A

40. Do you wear glasses or contacts? Y N

41. Do you live: on your own with roommates other

    with parents/guardians with partner

42. How many university credits are you taking this semester?

    0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6
    N/A

43. On a scale of 1 to 9 rate your enjoyment of academics:

    Not at all Very
    1 2 3 4 5 6 7 8 9

44. Have you ever received any extra assistance during your educational history? Y N

    Please circle any that apply and indicate when you received the assistance:
    E = Elementary school H = High school U = University

    a. Learning resource teacher E H U
    b. Tutor E H U
    c. Educational assistant E H U
    d. Speech Language Pathologist E H U
    e. Occupational Therapist E H U
    f. Physical Therapist (Physiotherapist) E H U
    g. Other: Please Specify: ______________________ E H U

45. Have you ever been diagnosed or classified as having a Learning Disorder? Y N

46. Do you consider yourself a musician? Y N

47. Have you ever considered yourself to be a musician? Y N
48. If you answered yes to either question 46 or 47, do/ did you play/perform:

a. Professionally
b. Recreationally
N/A

49. If you answered yes to either question 46 or 47, how long do/ did you play/perform for? N/A ____________

50. If you answered yes to either question 46 or 47, what age did you start playing/performing at? N/A ____________ years

51. How often do you listen to music? ____________ hours per week

52. Please indicate the type of music you listen to **most** often?
    a. Country
    b. Classical
    c. Rock
    d. R & B
    e. Blues
    f. Independent (Indie)
    g. Jazz
    h. Pop
    i. Electronic (house/dance)
    j. Folk
    k. Opera
    l. Acoustic/ soft rock
    m. Other: Provide brief details: __________________________

53. On a scale of 1 to 9, please rate your enjoyment of your life situation:

Not at all								Very
1	2	3	4	5	6	7	8	9

54. On a scale of 1 to 9, how stressful would you rate your day-to-day life?

Not at all								Very
1	2	3	4	5	6	7	8	9

55. What extracurricular sport(s) do/ did you play in:

    a. Elementary/ middle school:
        i. Please describe/ name the sport(s) AND indicate if it was recreational (R) or competitive (C)

____

        ii. How often did you play sports (per week)? ____________________
        iii. For each sport listed above, please indicate the last time you played each.

____

____

iv. For each sport listed above, please rank them in order from your favourite (most amount of time playing) to your least favourite (least amount of time playing).

____

____

b. High school:

i. Please describe/name the sport(s) AND indicate if it was recreational (R) or competitive (C)

____

ii. How often did you play sports (per week)? ______________________

iii. For each sport listed above, please indicate the last time you played each.

____

____

iv. For each sport listed above, please rank them in order from your favourite (most amount of time playing) to your least favourite (least amount of time playing).

____

____

c. University:

i. Please describe/name the sport(s) AND indicate if it was/is recreational (R) or competitive (C)

ii. How often do/did you play sports (per week)? ______________________

iii. For each sport listed above, please indicate the last time you played each.

____

____

iv. For each sport listed above, please rank them in order from your favourite (most amount of time playing) to your least favourite (least amount of time playing).

____

____

56. Do you exercise regularly? Y N

a. **If yes**, how many times a week do you exercise? _____
Please describe: ________________________________

____

57. When you ride a bike/skate/etc. do you wear a helmet? Y N N/A

58. Do you regularly engage in relaxation techniques (e.g., deep breathing or yoga): Y N
a. **If yes**, how many times a week do you engage in relaxation methods? ______
Please describe: ________________________________

59. Was last night's sleep typical for you? Y N

If No, what was different (better, worse)? ______________________

Why was it different (stress, room temperature, noise, etc.)?

____

60. Please indicate how well you slept last night by circling a number:

Worst possible sleep						Best possible sleep
1	2	3	4	5	6	7

61. Please indicate how you feel right now by circling a number:

Very sleepy						Very alert
1	2	3	4	5	6	7

62. Are you a shift worker? Y N

63. Have you had anything out of the ordinary occur in the past day or so? Y N
If yes, please explain:

____

____

64. Circle any of the following that apply to your experience over the past 6 months:

Moved	Death of a family member
New Job	Death of a close friend
Loss of Job	Financial Difficulties
Loss of Relationship	Illness of someone close to you
New Relationship	Personal Illness/Injury
Reconciliation with partner	New Baby
Reconciliation with Family	Wedding/ Engagement (self)
Divorce (of self or parents)	Vacation
Entered 1st year at university	Disrupted Sleep

Question 64 format adapted from Holmes, T. & Rahe, R (1967). "Holmes-Rahe life changes scale". *Journal of Psychosomatic Research*, Vol. 11, 213-218.

65. Please indicate how your day has been so far by circling a number:

Calm	1	2	3	4	5	6	7	8	9	10	Busy
Pleasant	1	2	3	4	5	6	7	8	9	10	Unpleasant
NOT Stressful	1	2	3	4	5	6	7	8	9	10	VERY Stressful

66. Please rate each of the following symptoms based on how you may have been affected during the past 2 months according to the following scale.

FREQUENCY	INTENSITY	DURATION
1 = Not at all	1 = Not at all	1 = Not at all
2 = Seldom	2 = Seldom	2 = A Few Seconds
3 = Often	3 = Clearly Present	3 = A Few Minutes
4 = Very Often	4 = Interfering	4 = A Few Hours
5 = All of the time	5 = Crippling	5 = Constant

	FREQUENCY	INTENSITY	DURATION
Headache			
Dizziness			
Irritability			
Memory Problems			
Difficulty Concentrating			
Fatigue			
Visual Disturbance			
Aggravated by Noise			
Judgment Problems			
Anxiety			

Question 66 from Gouvier et al. (1992)

Thank you for your time and consideration in completing this questionnaire! ☺

Everyday Living Questionnaire: Part II

Please fill in or circle an answer for each of the following. If you have any questions regarding clarification please ask the researcher. Thank you for your time and effort!

67. Since your first testing session, have you been hospitalized for (circle any that apply):
    a. Fractures Y N
    b. Illness Y N
    c. Surgery Y N
    d. Neurological complications Y N
    e. Other Y N

    If you answered Y to any of the above, briefly please provide details:
    e.g., How did it happen?
    ____
    ____

68. Since your first testing session, have you been diagnosed with a neurological condition? Y N

69. Since your first testing session, have you been diagnosed with a psychiatric condition? Y N

70. Since your first testing session, have you begun taking any of the following:

    a. Prescribed medication for a neurological psychiatric condition? Y N
        i. If yes, if you wish to describe what medication please do so: __________
    b. Prescribed medication for a psychiatric condition? Y N
        i. If yes, if you wish to disclose what medication please do so: __________
    c. Prescribed medication for a thyroid condition? Y N
    d. Oral contraception? Y N
    e. Medication for asthma, such as an inhaler? Y N

71. Since your first testing session, have you sustained an injury to your head with a force sufficient to alter your consciousness (e.g., dizziness, vomiting, seeing stars, loss of consciousness, or confusion)? Y N
    [If you answered **no** to this question you may move ahead to **question 19**]

If yes to question 5, please answer the following questions:

72. Did you experience these symptoms for more than 20 minutes? Y N

73. Did you experience a loss of consciousness associated with the head injury? Y N

    i. If so, how long was the loss of consciousness?
        1. [ ] < 5 minutes
        2. [ ] < 30 minutes
        3. [ ] < 24 hours
        4. [ ] < 1 week
        5. [ ] < 1 month
        6. [ ] > 1 month

74. If applicable, where did you strike your head?
    a. Front of the head
    b. Right side of the head
    c. Left side of the head

d. Other Provide brief details: ___________________________
e. I can't remember

75. How did you injure your head?
   i. [ ] Motor vehicle collision
   ii. [ ] Sports-related injury Please specify sport(s): ____
   iii. [ ] Falling
   iv. [ ] Other Please Specify:______________________________

76. Please briefly describe the incident during which the head injury occurred:

____

____

____

77. Please answer the following questions:

   a. Did the head injury result in a concussion? Y N

   b. Did it require stitches? Y N

   c. Did you receive medical treatment for your injury? Y N

   d. Did you stay overnight at a medical care facility? Y N

   e. Approximately how old were you at the time? ___

   f. How many months or year(s) have passed since you hit your head? ___

   g. Did the injury result in a litigation process of any sort? Y N

78. Since your first testing session, have you sustained *more than one* injury to your head with a force sufficient to alter your consciousness (e.g., dizziness, vomiting, seeing stars, loss of consciousness, or confusion)? Y N

[If you answered **no** to this question you may move ahead to **question 19**]

79. **If you answered yes to question 12**, did you experience these symptoms for more than 20 minutes? Y N

80. Did you experience a loss of consciousness associated with the least recent head injury? Y N
   a. If so, how long was the loss of consciousness?
      i. [ ] < 5 minutes
      ii. [ ] < 30 minutes
      iii. [ ] < 24 hours
      iv. [ ] < 1 week
      v. [ ] < 1 month
      vi. [ ] > 1 month

81. If applicable, where did you strike you head?
   a. Front of the head

b. Back of the head
c. Right side of the head
d. Left side of the head
e. Other Provide brief details: ___________________________
f. I can't remember

82. How did you injure your head?
    a. [ ] Motor vehicle collision
    b. [ ] Sports-related injury Please specify sport(s):
    ____
    c. [ ] Falling
    d. [ ] Other Please specify:______________________________

83. Please briefly describe the incident during which the least recent head injury occurred:

____

____

____

84. Please answer the following questions:

    a. Did the head injury result in a concussion? Y N

    b. Did it require stitches? Y N

    c. Did you receive medical treatment for your injury? Y N

    d. Did you stay overnight at a medical care facility? Y N

    e. Approximately how old were you at the time? ___

    f. How many months or year(s) have passed since you hit your head? ___

    g. Did the injury result in any litigation processes? Y N

***********If you were instructed to move ahead to question 19 please begin here*********

85. Since your first testing session, have you been involved in a litigation process of any sort? Y N

86. Since your first testing session, have you experienced any other neural trauma (e.g., stroke, anoxia)? Y N
    a. **If yes**, please explain:
    ____

    ____

87. Since your first testing session, have you made any changes in the following behaviours:
    a. Cigarette smoking? Y N
        i. If yes, have you (circle one):
            1. Started smoking
            2. Quit smoking

3. Changed frequency (circle: more or less)

b. Consuming alcohol? Y N
   i. If yes, have you (circle one):
      1. Started drinking
      2. Stopped drinking
      3. Changed frequency (circle: more or less)

c. Engage in performance enhancing drug use? Y N
   i. If yes, have you (circle one):
      1. Started taking performance enhancing drugs
      2. Stopped taking performance enhancing drugs

d. Engage in recreational drug use? Y N
   i. If yes, have you (circle one):
      1. Started engaging in recreational drug use
      2. Stopped engaging in recreational drug use
      3. Change frequency (circle: more or less)

88. Do you currently engage in recreational drug use? Y N
   a. If yes, do you engage in marijuana use? Y N
      i. If yes, please rate your marijuana use in the past 30 days:
         1. No use
         2. Once or twice
         3. Weekly
         4. Daily
      ii. If yes, have you had symptoms now you believe were caused or aggravated by marijuana use? Y N
      iii. If yes, what are your general motives for using marijuana? Select all that apply.
         1. To deal with anxiety
         2. To cope with pain
         3. For pleasure
         4. Other. Explain: ______________________________

   b. If you engage in recreational drug use, do you engage in other recreational drugs other than marijuana? Y N
      i. If yes, what other drugs do you normally engage in? _________________
      ii. If yes, please rate your other recreational drug use in the past 30 days:
         a. No use
         b. Once or twice
         c. Weekly
         d. Daily

89. Did you consume caffeine today (e.g., coffee, tea, energy drink, chocolate)? Y N

   a. **If yes**, how much?

      1   2   3   more than 3

   b. **If yes**, how much time has past since you last consumed caffeine today?

      Less than 1 hour   More than 1 hour

90. Since your last testing session, have you developed any new sensitivities to perfumes or scents?
    Y [ ] N [ ]

    Please rate your sensitivity:

Not at all								Very
1	2	3	4	5	6	7	8	9

91. Since your first testing session, have your living arrangements changed? Y N
If yes, do you now live: on your own with roommates other

with parents/guardians with partner

92. How many university credits are you taking this semester?

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6
N/A

93. Are you receiving any extra assistance? Y N

Please circle any that apply:

a. Learning resource teacher
b. Tutor
c. Educational assistant
d. Speech Language Pathologist
e. Occupational Therapist
f. Physical Therapist (Physiotherapist)
g. Other: Please Specify: ___________________________

94. Since your first testing session, have you been diagnosed or classified as having a Learning Disorder? Y N

95. Are you a shift worker? Y N

96. On a scale of 1 to 9, please rate your enjoyment of your life situation:

Not at all								Very
1	2	3	4	5	6	7	8	9

97. On a scale of 1 to 9, how stressful would you rate your day-to-day life?

Not at all								Very
2	2	3	4	5	6	7	8	9

98. What extracurricular sport(s) do you currently play?
   a. Please list sport(s) and indicate if it is recreational (R) or competitive (C)
   ____
   b. How many days of the week do you play sports:
      i. Now: ______
      ii. During athletic season: _____
   c. For the sport(s) listed above, when is the last time you play it/them?
   ____
   d. Please indicate, from the sport(s) that you play, which is your favourite?
   ____

99. When you ride a bike/skate/etc. do you wear a helmet? Y N N/A

100. Do you regularly engage in relaxation techniques (e.g., deep breathing or yoga): Y N
a. **If yes**, how many times a week do you engage in relaxation methods? ______

Please describe: ____

101. Was last night's sleep typical for you? Y N

If No, what was different (better, worse)? ___________________________

Why was it different (stress, room temperature, noise, etc.)? ________________

102. Please indicate how well you slept last night by circling a number:

Worst possible sleep						Best possible sleep
1	2	3	4	5	6	7

103. Please indicate how you feel right now by circling a number:

Very sleepy						Very alert
1	2	3	4	5	6	7

104. Have you had anything out of the ordinary occur in the past day or so? Y N
If yes, please explain:

____

____

105. Circle any of the following that apply to your experience since your first testing session:

Moved	Death of a family member
New Job	Death of a close friend
Loss of Job	Financial Difficulties
Loss of Relationship	Illness of someone close to you
New Relationship	Personal Illness/Injury
Reconciliation with partner	New Baby
Reconciliation with Family	Wedding/ Engagement (self)
Divorce (of self or parents)	Vacation
Entered 1st year at university	Disrupted Sleep

Question 39 format adapted from Holmes, T. & Rahe, R (1967). "Holmes-Rahe life changes scale". *Journal of Psychosomatic Research*, Vol. 11, 213-218.

106. Please indicate how your day has been so far by circling a number:

Calm	1	2	3	4	5	6	7	8	9	10	Busy
Pleasant	1	2	3	4	5	6	7	8	9	10	Unpleasant
NOT Stressful	1	2	3	4	5	6	7	8	9	10	VERY Stressfu

107. Please rate each of the following symptoms based on how you may have been affected during the past 2 months according to the following scale.

FREQUENCY	INTENSITY	DURATION
1 = Not at all	1 = Not at all	1 = Not at all
2 = Seldom	2 = Seldom	2 = A Few Seconds
3 = Often	3 = Clearly Present	3 = A Few Minutes
4 = Very Often	4 = Interfering	4 = A Few Hours
5 = All of the time	5 = Crippling	5 = Constant

	FREQUENCY	INTENSITY	DURATION
Headache			
Dizziness			
Irritability			
Memory Problems			
Difficulty Concentrating			
Fatigue			
Visual Disturbance			
Aggravated by Noise			
Judgment Problems			
Anxiety			

Question 41 from Gouvier et al. (1992)

Thank you for your time and consideration in completing this questionnaire! ☺

Appendix B

Brock University Research Ethics Board Approval

Brock University
Research Ethics Office
Tel: 905-688-5550 ext. 3035
Email: reb@brocku.ca

Social Science Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE: 9/8/2014

PRINCIPAL INVESTIGATOR: GOOD, Dawn - Psychology

FILE: 13-310 - GOOD

TYPE: Masters Thesis/Project STUDENT: Nicole Barry
SUPERVISOR: Dawn Good

TITLE: The Effect of Concussion in Athletes and Premorbid Moderators of Outcome

ETHICS CLEARANCE GRANTED

Type of Clearance: NEW Expiry Date: 9/30/2015

The Brock University Social Science Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from 9/8/2014 to 9/30/2015.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before 9/30/2015. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page at http://www.brocku.ca/research/policies-and-forms/research-forms.

In addition, throughout your research, you must report promptly to the REB:

a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
c) New information that may adversely affect the safety of the participants or the conduct of the study;
d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved: [redacted]

Jan Frijters, Chair
Social Science Research Ethics Board

Note: Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.

Appendix C

Statistical Analyses and Tables

Appendix C Table of Contents

Table C1

Additional Self-reported Sport-related Activities Currently Played

Level of Risk of Primary Sport	*Second Sport n= 27*	*Third Sport n= 11*	*Fourth Sport n= 4*
High-risk Athlete			
High-risk Sport	6	1	2
Low-risk Sport	6	4	2
Low-risk Athlete			
High-risk Sport	0	3	0
Low-risk Sport	15	3	0

Table C2

Indicators of Severity and Etiology of Injury of Second Self-reported MHI

	High-risk Athlete *n*= 5		*Low-risk Athlete* *n*= 4		*Non-athlete* *n*= 3	
Location of injury	*n*	% (of total)	*n*	%	*n*	%
Front of head	3	25.0	1	8.3	0	0
Right side of head	0	0	1	8.3	0	0
Back of head	0	0	0	0	2	16.7
Could not recall	2	16.7	2	16.7	1	8.3
Indicators of severity						
Symptoms 20+ minutes	4	33.3	1	8.3	0	0
LOC	3	25.0	2	16.7	1	8.3
Duration of LOC						
Less than 5 minutes	3	25.0	2	16.7	0	0
Less than 30 minutes	0	0	0	0	1	8.3
Self-reported concussion	4	33.3	4	33.3	2	16.7
Received medical treatment	2	16.7	4	33.3	1	8.3
Stayed overnight in medical facility	1	8.3	1	0	0	0
Time since injury						
9-12 months	1	8.3	0	0	0	0
1-3 years	1	8.3	0	0	1	8.3
3-5 years	0	0	1	8.3	0	0
5 years or more	3	25.0	3	25.0	2	16.7
Etiology						
High-risk sport	3	25.0	3	25.0	1	8.3
Low-risk sport	0	0	0	0	1	8.3
MVC	1	8.3	0	0	0	0
Falling	1	8.3	1	8.3	1	8.3

Table C3

Level of Education Completed and Associated Frequencies and Percentages of the Sample by MHI Status

Level of Education	*n*	*Percentage*
High school (grade 12)		
MHI	8	25.00
No-MHI	13	28.89
One year post-secondary		
MHI	6	18.75
No-MHI	4	9.09
Two years post-secondary		
MHI	3	9.38
No-MHI	7	15.91
Three years post-secondary		
MHI	7	21.87
No-MHI	12	27.27
Four years post-secondary		
MHI	7	21.87
No-MHI	8	18.18
Greater than four years post-secondary		
MHI	1	3.13
No-MHI	0	0

Note: One participant (no-MHI) did not report their level of education.

Table C4

Self-identified Ethnicity and Associated Frequencies and Percentages of the Sample by MH Status

Ethnic Group	*n*	*Percentage*
Caucasian		
MHI	25	78.13
No-MHI	25	56.82
European		
MHI	3	9.36
No-MHI	6	13.64
African		
MHI	1	3.13
No-MHI	1	2.27
Hispanic		
MHI	0	0
No-MHI	2	4.54
Chinese		
MHI	0	0
No-MHI	1	2.27
East Indian		
MHI	0	0
No-MHI	2	4.54
West Indian		
MHI	1	3.13
No-MHI	1	2.27
Other		
MHI	2	6.25
No-MHI	7	15.91

Table C5

Faculty of Study and Associated Frequencies and Percentages of the Sample by MHI Status

Faculty of Study in Post-Secondary	*n*	*Percentage*
Social Sciences		
MHI	8	25.00
No-MHI	10	22.72
Humanities		
MHI	1	3.12
No-MHI	4	9.09
Maths and Sciences		
MHI	6	18.75
No-MHI	10	22.72
Applied Health Sciences		
MHI	14	43.75
No-MHI	16	36.36
Business		
MHI	2	6.25
No-MHI	3	6.81
Education		
MHI	1	3.12
No-MHI	2	4.45

Table C6

Chi-square Tests of Independence for Time of Day Effects

Variable	*Chi-square*	*df*	*p*
MHI	2.781	2	.249
Athletic Status	5.944	4	.203
Sex	.100	2	.951

Table C7

Chi-square Tests of Independence for Tester Effects

Variable	*Chi-square*	*df*	*p*
MHI	5.850	4	.211
Athletic Status	9.664	8	.287
Sex	8.718	4	.069

Table C8

Chi-square Tests of Independence for Health-related Variables for MHI and Athletic Status

Variable	*Chi-square*	*df*	*p*
Hospitalizations for Fractures	5.559	1	.062
Hospitalizations for Illness	.777	1	.492
Hospitalizations for Surgery	.173	1	.211
Hospitalizations for Other	.703	1	.644
Diagnosed Psychiatric Condition	.080	1	1.000
Medication for a Psychiatric or Neurological Condition	.822	1	.477
Sensitivity of Scents	.069	1	.793
Oral Contraception Use	.160	1	.690
Medication for Asthma	1.655	1	.198

Note: Fisher’s Exact Test was used when cells had a count less than five (see Fisher, 1948).

Table C9

Frequencies of MHI and Sex for Hospitalizations for Illness

Hospitalizations for Illness	*No*	*Yes*
Female		
No MHI	18	13
MHI	11	4
Total	29	17
Male		
No MHI	8	6
MHI	9	8
Total	17	14
Total		
No MHI	26	19
MHI	20	12

Table C10

Chi-square Tests of Independence for Health-related Variables for MHI and Sex

Variable	*Chi-square*	*df*	*p*
Hospitalizations for Fractures	2.095	1	.148
Hospitalizations for Illness	.081	1	.777
Hospitalizations for Surgery	3.656	1	.075
Hospitalizations for Other	.833	1	1.000
Diagnosed Psychiatric Condition	.244	1	1.000
Medication for a Psychiatric or Neurological Condition	.225	1	1.000
Sensitivity of Scents	1.298	1	.326
Medication for Asthma	.533	1	1.000

Note: Fisher's Exact Test was used when cells had a count less than five (see Fisher, 1948).

Table C11

Chi-square Tests of Independence of Extra Assistance Variables for MHI and Athletic Status

Variable	*Chi-square*	*df*	*p*
Learning Disorder	.939	2	.625
Tutor	3.860	2	.145
Speech Language Pathologist	2.311	2	.315
Physiotherapist	4.055	2	.088

Table C12

Chi-square Tests of Independence of Extra Assistance Variables for MHI and Sex

Variable	*Chi-square*	*df*	*p*
Leaning Disorder	3.704	1	.091
Extra Assistance	3.521	1	.109
Learning Resource Teacher	4.278	1	.109
Tutor	1.143	1	.403
Educational Assistant	.139	1	1.000
Speech Language Pathologist	1.742	1	.464
Occupational Therapist	3.768	1	.063
Physiotherapist	3.592	1	.106
‘Other” Extra Assistance	.313	1	1.000

Table C13

Frequencies of MHI and Athletic Status for Extra Assistance

Received Extra Assistance	*No*	*Yes*
Non-athlete		
No MHI	10	8
MHI	4	2
Total	14	10
Low-risk Athlete		
No MHI	12	9
MHI	3	4
Total	15	13
High-risk Athlete		
No MHI	4	2
MHI	12	7
Total	16	9
Total		
No MHI	26	19
MHI	19	13

Table C14

Frequencies of MHI and Athletic Status for Having a Learning Resource Teacher

Learning Resource Teacher	*No*	*Yes*
Non-athlete		
No MHI	14	4
MHI	6	0
Total	20	4
Low-risk Athlete		
No MHI	18	3
MHI	6	1
Total	24	4
High-risk Athlete		
No MHI	6	0
MHI	16	3
Total	22	3
Total		
No MHI	38	7
MHI	28	4

Table C15

Chi-square Tests of Independence of Extra Assistance Variables for MHI and Athletic Status Separately

Variable	*Chi-square*	*df*	*p*
MHI Status			
Occupational Therapist	.233	1	.416
'Other' Assistance	.312	1	.395
Athletic Status			
Occupational Therapist	1.773	2	.412
Speech Language Pathologist	2.311	2	.315
Physiotherapist	4.055	2	.088

Table C16

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Number of Courses Enrolled in

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.512	.007	.477
Athletic Status	2	.518	.015	.562
MHI X Athletic Status	2	2.717	.071	.073
Error	70			

Table C17

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Enjoyment of Academics

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.049	.001	.825
Athletic Status	2	1.101	.030	.338
MHI X Athletic Status	2	.472	.013	.626
Error	71			

Table C18

A 2 (MHI Status) X 2 (Sex) ANOVA for Number of Courses Enrolled in

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.053	.001	.818
Sex	1	.524	.007	.471
MHI X Sex	1	1.764	.024	.188
Error	72			

Table C19

A 2 (MHI Status) X 2 (Sex) ANOVA for Number of Enjoyment of Academics

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.165	.002	.686
Sex	1	.578	.007	.449
MHI X Sex	1	3.549	.046	.064
Error	73			

Table C20

Chi-square Tests of Independence of MHI and Athletic Status for Cigarette Smoking

Variable	*Chi-square*	*df*	*p*
Smoke Cigarettes	5.000	2	.082

Table C21

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Drinks Consumed per Outing

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	1.241	.017	.269
Athletic Status	2	.848	.024	.433
MHI X Athletic Status	2	.751	.021	.476
Error	65			

Table C22

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Drinks Consumed per Week

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.093	.001	.762
Athletic Status	2	.419	.012	.659
MHI X Athletic Status	2	.001	.000	.999
Error	70			

Table C23

Frequencies of MHI and Athletic Status for Recreational Drug Use

Recreational Drug Use	*No*	*Yes*
Non-athlete		
No MHI	10	8
MHI	6	0
Total	16	8
Low-risk Athlete		
No MHI	18	3
MHI	5	2
Total	23	5
High-risk Athlete		
No MHI	5	1
MHI	11	8
Total	16	9
Total		
No MHI	33	12
MHI	22	10

Table C24

Frequencies of MHI and Athletic Status for Alcohol Consumption

Alcohol Use	*No*	*Yes*
Non-athlete		
No MHI	11	7
MHI	3	3
Total	14	10
Low-risk Athlete		
No MHI	15	6
MHI	2	5
Total	27	11
High-risk Athlete		
No MHI	4	2
MHI	13	6
Total	17	8
Total		
No MHI	30	15
MHI	18	14

Table C25

Chi-square Tests of Independence of Substance Consumption Variables for MHI and Sex

Variable	*Chi-square*	*df*	*p*
Smoke Cigarettes	1.875	1	.400
Consume Alcohol	4.050	1	.092
Recreational Drug Use	.733	1	.670
Marijuana Use	1.308	1	.402

Table C26

A 2 (MHI Status) X 2 (Sex) ANOVA for Drinks Consumed per Outing

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	2.143	.029	.148
Sex	1	3.819	.051	.055
MHI X Sex	1	.466	.006	.497
Error	72			

Table C27

A 2 (MHI Status) X 2 (Sex) ANOVA for Drinks Consumed per Week

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.378	.005	.541
Sex	1	1.477	.020	.228
MHI X Sex	1	.402	.005	.528
Error	72			

Table C28

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Sleep Rating

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.005	.000	.947
Athletic Status	2	.436	.011	.649
MHI X Athletic Status	2	1.394	.037	.225
Error	71			

Table C29

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Current Alertness

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.207	.003	.650
Athletic Status	2	1.462	.039	.239
MHI X Athletic Status	2	.363	.010	.697
Error	71			

Table C30

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Enjoyment of Current Life Situation

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	2.003	.024	.161
Athletic Status	2	1.216	.029	.303
MHI X Athletic Status	2	2.360	.057	.102
Error	71			

Table C31

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Total Life Stressors

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.758	.010	.387
Athletic Status	2	1.459	.038	.239
MHI X Athletic Status	2	.724	.019	.489
Error	71			

Table C32

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Self-reported Day-to-day Stress

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	5.153	.066	.026*
Athletic Status	2	.603	.015	.550
MHI X Athletic Status	2	.814	.021	.447
Error	71			

Note: *$p < .05$

Table C33

A 2 (MHI Status) X 2 (Sex) ANOVA for Sleep Rating

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.094	.001	.760
Sex	1	1.841	.024	.179
MHI X Sex	1	.458	.006	.501
Error	73			

Table C34

A 2 (MHI Status) X 2 (Sex) ANOVA for Current Alertness

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.246	.003	.621
Sex	1	10.767	.124	.002**
MHI X Sex	1	.976	.011	.326
Error	73			

Note: ***p* < .01

Table C35

A 2 (MHI Status) X 2 (Sex) ANOVA for Life Enjoyment

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.826	.011	.366
Sex	1	.267	.004	.607
MHI X Sex	1	.002	.000	.967
Error	73			

Table C36

A 2 (MHI Status) X 2 (Sex) ANOVA for Total Life Stressors

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.704	.009	.404
Sex	1	2.421	.032	.124
MHI X Sex	1	.017	.000	.896
Error	73			

Table C37

A 2 (MHI Status) X 2 (Sex) ANOVA for Day-to-day Stress

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	6.227	.077	.015*
Sex	1	2.642	.031	.108
MHI X Sex	1	.188	.002	.666
Error	73			

Note: $^*p < .05$

Table C38

One-way ANOVA for MHI Status on PCS Total

Source	*df*	*F*	η^2	*p*
MHI	1	2.192	.030	.143
Error	71			

Table C39

One-way ANOVA for MHI Status on PCS Frequency Total

Source	*df*	*F*	η^2	*p*
MHI	1	3.878	.052	.053
Error	74			

Table C40

One-way ANOVA for MHI Status on PCS Intensity Total

Source	*df*	*F*	η^2	*p*
MHI	1	1.972	.026	.164
Error	75			

Table C41

One-way ANOVA for MHI Status on PCS Duration Total

Source	*df*	*F*	η^2	*p*
MHI	1	1.029	.014	.314
Error	75			

Table C42

One-way ANOVA for MHI Status on PCS Headache

Source	*df*	*F*	η^2	*p*
MHI	1	4.004	.053	.049*
Error	72			

Note: *$p < .05$

Table C43

One-way ANOVA for MHI Status on PCS Irritability

Source	*df*	*F*	η^2	*p*
MHI	1	5.739	.072	.019*
Error	74			

Note: *$p < .05$

Table C44

One-way ANOVA for MHI Status on PCS Anxiety

Source	*df*	*F*	η^2	*p*
MHI	1	4.307	.055	.041*
Error	74			

Note: *p < .05

Table C45

One-way ANOVA for MHI Status on PCS Dizziness

Source	*df*	*F*	η^2	*p*
MHI	1	3.310	.043	.073
Error	74			

Table C46

One-way ANOVA for MHI Status on PCS Fatigue

Source	*df*	*F*	η^2	*p*
MHI	1	2.947	.038	.090
Error	74			

Table C47

One-way ANOVA for MHI Status on PCS Memory Problems

Source	*df*	*F*	η^2	*p*
MHI	1	1.021	.041	.316
Error	74			

Table C48

One-way ANOVA for MHI Status on PCS Difficulty Concentrating

Source	*df*	*F*	η^2	*p*
MHI	1	.032	.000	.858
Error	74			

Table C49

One-way ANOVA for MHI Status on PCS Visual Disturbance

Source	*df*	*F*	η^2	*p*
MHI	1	1.326	.018	.253
Error	74			

Table C50

One-way ANOVA for MHI Status on PCS Aggravated by Noise

Source	*df*	*F*	η^2	*p*
MHI	1	2.100	.028	.152
Error	74			

Table C51

One-way ANOVA for MHI Status on PCS Judgment Problems

Source	*df*	*F*	η^2	*p*
MHI	1	2.356	.031	.129
Error	73			

Table C52

PCS Symptoms for Individuals With and Without a History of MHI

PCS	*Frequency M (SD)*	*Intensity M (SD)*	*Duration M (SD)*	*Overall M (SD)*
Total PCS				
No MHI	19.156 (5.616)	19.933 (5.467)	23.136 (6.815)	62.204 (17.106)
MHI	22.032 (7.097)	21.812 (6.218)	24.656 (5.900)	68.551 (19.113)
Headache				
No MHI	1.98 (.621)	2.33 (.953)	3.00 (1.161)	7.295 (2.529)
MHI	2.74 (1.290)	2.75 (1.191)	3.19 (1.161)	8.633 (3.211)
Dizziness				
No MHI	1.38 (.684)	1.44 (.755)	1.40 (.654)	4.222 (1.941)
MHI	1.88 (1.070)	1.91 (1.228)	1.69 (.738)	5.469 (2.688)
Irritability				
No MHI	2.16 (.903)	2.16 (.928)	2.51 (1.079)	6.844 (2.688)
MHI	2.56 (.982)	2.63 (1.070)	3.03 (1.092)	8.774 (4.387)
Memory Problems				
No MHI	2.07 (1.116)	2.11 (1.133)	2.33 (1.834)	6.511 (3.415)
MHI	2.31 (1.330)	2.22 (1.128)	2.33 (1.834)	6.511 (3.415)
Difficulty Concentrating				
No MHI	2.60 (1.074)	2.80 (1.140)	3.24 (1.228)	8.667 (3.096)
MHI	2.66 (1.153)	2.59 (.979)	3.25 (1.136)	8.806 (3.655)
Fatigue				
No MHI	2.36 (1.151)	2.31 (1.083)	3.00 (1.477)	7.667 (3.535)
MHI	2.81 (1.203)	2.72 (1.085)	3.44 (1.243)	9.096 (3.618)
Visual Disturbance				
No MHI	1.33 (.769)	1.36 (.802)	1.69 (1.794)	4.378 (2.902)
MHI	1.47 (.879)	1.44 (.914)	1.50 (.984)	5.935 (8.398)
Aggravated by Noise				
No MHI	2.02 (1.77)	2.16 (1.242)	2.27 (1.372)	6.444 (3.696)
MHI	1.78 (1.128)	1.75 (.979)	1.75 (1.047)	5.290 (2.946)
Judgment Problems				
No MHI	1.38 (.614)	1.33 (.953)	1.36 (.679)	4.067 (1.711)
MHI	1.53 (1.016)	1.41 (.953)	1.59 (1.241)	4.967 (3.337)

Anxiety				
No MHI	1.89 (1.005)	1.93 (1.053)	2.31 (1.328)	6.133 (3.173)
MHI	2.50 (1.244)	2.56 (1.105)	2.84 (1.194)	7.709 (3.368)

Table C53

One-way ANOVA for Athletic Status on Number of Head Injuries

Source	*df*	*F*	η^2	*p*
Athletic Status	2	5.678	.133	.005**
Error	74			

Note: $^{**}p < .01$

Table C54

One-way ANOVAs for MHI Status for all Neuropsychological Measures

Measure	*df*	*F*	η^2	*p*
SDMT Total Score	1	1.259	.017	.265
Error	75			
SDMT Errors	1	1.154	.001	.286
Error	75			
LNS	1	.734	.009	.394
Error	75			
TMT-II Time	1	2.037	.026	.158
Error	75			
TMT-II Errors	1	2.226	.026	.158
Error	75			
TMT-IV Time	1	.159	.002	.691
Error	75			
TMT-IV Errors	1	.094	.001	.760
Error	75			

Table C55

Means and Standard Deviations for Neuropsychological Measures for Individuals with MHI and without MHI

Neuropsychological Measure	*Mean*	*Standard Deviation*
SDMT Total Score		
MHI	60.719	9.024
No MHI	58.222	10.020
SDMT Errors		
MHI	.500	1.107
No MHI	.778	1.126
LNS Total Score		
MHI	19.156	2.974
No MHI	18.511	3.441
TMT-II Total Time		
MHI	27.257	8.718
No MHI	30.859	12.222
TMT-II Total Errors		
MHI	.000	.000
No MHI	.067	.252
TMT-IV Total Time		
MHI	77.534	37.659
No MHI	74.402	31.100
TMT-IV Total Errors		
MHI	1.281	1.373
No MHI	1.156	2.011

Table C56

Correlation Table for Number of Self-reported MHIs on Neuropsychological Measures

Variables	*Number of MHIs*
SDMT Time	-.048
SDMT Errors	.107
LNS	-.004
TMT-II Time	.079
TMT-IV Time	.081
TMT-IV Errors	.004

Table C57

One-way ANOVA for MHI Status on WRAT-IV Spelling Subtest Total Score

Source	*df*	*F*	η^2	*p*
MHI	1	.000	.000	.999
Error	75			

Table C58

One-way ANOVA for MHI Status by WRAT-IV Word Reading Subtest Total Score

Source	*df*	*F*	η^2	*p*
MHI	1	2.651	.034	.108
Error	75			

Table C59

One-way ANOVA for MHI Status by WRAT-IV Word Reading Subtest Total Time

Source	*df*	*F*	η^2	*p*
MHI	1	5.264	.072	.025*
Error	75			

Note: * $p < .05$

Table C60

Means and Standard Deviations for WRAT-IV Spelling and Word Reading Subtests for Individuals with MHI and without MHI

WRAT-IV Subtest	*Mean*	*Standard Deviation*
Spelling		
MHI	44.645	5.225
No MHI	44.644	3.290
Word Reading Total Score		
MHI	61.281	5.225
No MHI	58.600	7.898
Word Reading Total Time		
MHI	70.373	17.698
No MHI	1.826	22.626

Table C61

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Impulsivity (UPPS-P)

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.488	.007	.487
Athletic Status	2	1.230	.036	.299
MHI X Athletic Status	2	.900	.026	.412
Error	65			

Table C62

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Sensation Seeking (UPPS-P)

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	1.948	.025	.167
Athletic Status	2	.860	.022	.428
MHI X Athletic Status	2	.685	.017	.508
Error	70			

Table C63

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Negative Urgency (UPPS-P)

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.233	.003	.631
Athletic Status	2	.489	.014	.615
MHI X Athletic Status	2	.054	.001	.947
Error	69			

Table C64

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Premeditation (UPPS-P)

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.066	.001	.798
Athletic Status	2	2.116	.057	.128
MHI X Athletic Status	2	1.509	.041	.228
Error	69			

Table C65

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Perseverance (UPPS-P)

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.327	.004	.569
Athletic Status	2	1.143	.031	.325
MHI X Athletic Status	2	.391	.010	.678
Error	70			

Table C66

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Positive Urgency (UPPS-P)

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	1.479	.020	.228
Athletic Status	2	1.083	.029	.344
MHI X Athletic Status	2	.190	.005	.827
Error	70			

Table C67

Means and Standard Deviations for Impulsivity for MHI and Athletic Status

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	128.286	29.911
Low-risk Athlete	127.050	17.422
High-risk Athlete	129.333	13.366
MHI		
Non-athlete	133.000	26.929
Low-risk Athlete	111.471	18.329
High-risk Athlete	126.833	26.516
Athletic Status Total		
Non-athlete	129.700	28.424
Low-risk Athlete	123.037	18.631
High-risk Athlete	127.458	23.659
MHI Status Total		
MHI	124.581	25.362
No MHI	127.825	21.673

Table C68

Means and Standard Deviations for Sensation Seeking (UPPS-P) for MHI and Athletic Status

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	31.055	8.142
Low-risk Athlete	36.238	6.057
High-risk Athlete	34.167	5.077
MHI		
Non-athlete	36.667	9.913
Low-risk Athlete	35.857	7.151
High-risk Athlete	37.944	7.033
Athletic Status Total		
Non-athlete	32.308	8.632
Low-risk Athlete	36.142	6.211
High-risk Athlete	37.000	6.705
MHI Status Total		
MHI	37.032	7.472
No MHI	33.889	7.152

Table C69

Means and Standard Deviations for Negative Urgency (UPPS-P) for MHI and Athletic Status

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	29.889	8.238
Low-risk Athlete	27.250	5.542
High-risk Athlete	28.477	4.719
MHI		
Non-athlete	28.883	9.432
Low-risk Athlete	27.142	7.313
High-risk Athlete	26.722	7.528
Athletic Status Total		
Non-athlete	29.625	8.350
Low-risk Athlete	27.222	5.889
High-risk Athlete	27.960	6.873
MHI Status Total		
MHI	27.226	7.636
No MHI	28.477	6.673

Table C70

Means and Standard Deviations for Premeditation (UPPS-P) for MHI and Athletic Status

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	22.186	5.958
Low-risk Athlete	21.952	5.172
High-risk Athlete	28.477	4.535
MHI		
Non-athlete	25.500	6.221
Low-risk Athlete	19.427	4.392
High-risk Athlete	22.985	6.136
Athletic Status Total		
Non-athlete	23.091	6.070
Low-risk Athlete	21.321	5.034
High-risk Athlete	23.360	5.765
MHI Status Total		
MHI	22.625	5.983
No MHI	22.443	5.369

Table C71

Means and Standard Deviations for Perseverance (UPPS-P) for MHI and Athletic Status

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	21.059	5.494
Low-risk Athlete	19.952	3.186
High-risk Athlete	19.167	4.916
MHI		
Non-athlete	21.000	5.177
Low-risk Athlete	17.714	4.821
High-risk Athlete	19.316	5.143
Athletic Status Total		
Non-athlete	21.044	5.296
Low-risk Athlete	19.316	3.695
High-risk Athlete	19.280	5.143
MHI Status Total		
MHI	19.281	5.030
No MHI	20.273	4.385

Table C72

Means and Standard Deviations for Positive Urgency (UPPS-P) for MHI and Athletic Status

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	30.667	12.833
Low-risk Athlete	27.238	7.475
High-risk Athlete	28.000	6.132
MHI		
Non-athlete	27.833	13.182
Low-risk Athlete	27.857	8.414
High-risk Athlete	26.500	9.811
Athletic Status Total		
Non-athlete	29.958	12.691
Low-risk Athlete	25.893	7.922
High-risk Athlete	26.500	8.931
MHI Status Total		
MHI	25.710	10.119
No MHI	28.711	9.797

Table C73

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Aggression (BPAQ)

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	1.280	.017	.262
Athletic Status	2	.458	.011	.634
MHI X Athletic Status	2	2.968	.072	.058
Error	70			

Table C74

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Physical Aggression (BPAQ)

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	2.097	.040	.152
Athletic Status	2	.352	.010	.705
MHI X Athletic Status	2	2.741	.078	.071
Error	70			

Table C75

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Anger (BPAQ)

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	3.035	.039	.086
Athletic Status	2	1.132	.034	.271
MHI X Athletic Status	2	.948	.024	.392
Error	70			

Table C76

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Hostility (BPAQ)

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.146	.002	.704
Athletic Status	2	.278	.007	.758
MHI X Athletic Status	2	1.926	.051	.153
Error	71			

Table C77

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Verbal Aggression (BPAQ)

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.251	.003	.618
Athletic Status	2	.938	.025	.396
MHI X Athletic Status	2	.812	.021	.448
Error	70			

Table C78

Means and Standard Deviations for Aggression (BPAQ) for MHI and Athletic Status

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	74.000	16.971
Low-risk Athlete	68.571	18.121
High-risk Athlete	61.000	18.396
MHI		
Non-athlete	72.167	19.498
Low-risk Athlete	66.333	20.539
High-risk Athlete	81.889	18.493
Athletic Status Total		
Non-athlete	73.522	17.220
Low-risk Athlete	68.074	18.292
High-risk Athlete	76.667	20.290
MHI Status Total		
MHI	76.833	19.543
No MHI	69.636	17.824

Table C79

Means and Standard Deviations for Physical Aggression (BPAQ) for MHI and Athletic Status

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	19.333	6.490
Low-risk Athlete	19.380	7.723
High-risk Athlete	16.167	6.047
MHI		
Non-athlete	19.333	7.815
Low-risk Athlete	17.714	7.825
High-risk Athlete	25.444	7.950
Athletic Status Total		
Non-athlete	19.333	6.664
Low-risk Athlete	18.964	7.638
High-risk Athlete	23.125	8.456
MHI Status Total		
MHI	22.516	8.414
No MHI	18.933	6.982

Table C80

Means and Standard Deviations for Anger (BPAQ) for MHI and Athletic Status

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	17.823	4.746
Low-risk Athlete	15.095	5.156
High-risk Athlete	12.167	2.787
MHI		
Non-athlete	18.333	7.607
Low-risk Athlete	17.000	7.594
High-risk Athlete	17.789	6.579
Athletic Status Total		
Non-athlete	17.956	5.439
Low-risk Athlete	15.571	5.763
High-risk Athlete	16.440	6.332
MHI Status Total		
MHI	17.718	6.770
No MHI	15.750	5.035

Table C81

Means and Standard Deviations for Hostility (BPAQ) for MHI and Athletic Status

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	23.111	5.246
Low-risk Athlete	20.381	5.427
High-risk Athlete	18.500	7.007
MHI		
Non-athlete	19.667	3.445
Low-risk Athlete	22.143	6.817
High-risk Athlete	21.500	5.156
Athletic Status Total		
Non-athlete	22.250	5.024
Low-risk Athlete	20.821	5.722
High-risk Athlete	21.040	5.682
MHI Status Total		
MHI	21.500	5.212
No MHI	21.222	5.692

Table C82

Means and Standard Deviations for Verbal Aggression (BPAQ) for MHI and Athletic Status

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	14.667	3.678
Low-risk Athlete	14.333	3.967
High-risk Athlete	14.333	5.715
MHI		
Non-athlete	15.667	4.926
Low-risk Athlete	13.000	3.406
High-risk Athlete	16.316	3.859
Athletic Status Total		
Non-athlete	14.917	3.933
Low-risk Athlete	14.037	3.827
High-risk Athlete	16.316	4.327
MHI Status Total		
MHI	15.548	4.073
No MHI	14.467	4.015

Table C83

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Sensation Seeking (UPPS-P) Excluding Individuals with a Diagnosed Psychiatric Condition

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	5.961	.087	.018*
Athletic Status	2	.054	.002	.947
MHI X Athletic Status	2	1.345	.039	.268
Error	59			

Note: *p < .05

Table C84

Means and Standard Deviations for Sensation Seeking (UPPS-P) for MHI and Athletic Status Excluding Individuals with a Diagnosed Psychiatric Condition

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	31.929	8.471
Low-risk Athlete	36.000	6.155
High-risk Athlete	34.167	5.076
MHI		
Non-athlete	41.750	1.500
Low-risk Athlete	37.400	7.335
High-risk Athlete	38.000	7.246
Athletic Status Total		
Non-athlete	34.111	8.540
Low-risk Athlete	36.292	6.272
High-risk Athlete	38.000	6.856
MHI Status Total		
MHI	38.462	6.677
No MHI	34.257	7.029

Table C85

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for Physical Aggression (BPAQ) Excluding Individuals with a Diagnosed Psychiatric Condition

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	3.036	.043	.087
Athletic Status	2	.250	.007	.780
MHI X Athletic Status	2	1.750	.050	.183
Error	59			

Table C86

Means and Standard Deviations for Physical Aggression (BPAQ) for MHI and Athletic Status Excluding Individuals with a Diagnosed Psychiatric Condition

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	17.929	5.954
Low-risk Athlete	19.368	7.932
High-risk Athlete	16.167	6.047
MHI		
Non-athlete	20.250	7.805
Low-risk Athlete	19.400	8.735
High-risk Athlete	25.529	8.382
Athletic Status Total		
Non-athlete	18.444	6.233
Low-risk Athlete	19.375	7.906
High-risk Athlete	20.087	8.644
MHI Status Total		
MHI	23.539	8.382
No MHI	18.359	6.934

Table C87

Means and Standard Deviations for Competitiveness (MC) for MHI and Athletic Status

MHI/Athletic Status	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	83.056	14.407
Low-risk Athlete	95.952	8.096
High-risk Athlete	99.000	20.900
MHI		
Non-athlete	93.933	12.750
Low-risk Athlete	99.000	13.292
High-risk Athlete	103.842	14.332
Athletic Status Total		
Non-athlete	85.750	14.543
Low-risk Athlete	96.714	9.498
High-risk Athlete	102.680	15.789
MHI Status Total		
MHI	100.906	13.994
No MHI	91.200	14.347

Table C88

One-way ANOVA for MHI Status on Levels of Endorsed Impulsivity (UPPS-P)

Source	*df*	*F*	η^2	*p*
MHI	1	.337	.005	.536
Error	69			

Table C89

One-way ANOVA for MHI Status on Levels of Endorsed Negative Urgency (UPPS-P)

Source	*df*	*F*	η^2	*p*
MHI	1	.567	.008	.454
Error	73			

Table C90

One-way ANOVA for MHI Status on Levels of Endorsed Premeditation (UPPS-P)

Source	*df*	*F*	η^2	*p*
MHI	1	.019	.000	.890
Error	73			

Table C91

One-way ANOVA for MHI Status on Levels of Endorsed Perseverance (UPPS-P)

Source	*df*	*F*	η^2	*p*
MHI	1	.836	.011	.363
Error	74			

Table C92

One-way ANOVA for MHI Status on Levels of Endorsed Positive Urgency (UPPS-P)

Source	*df*	*F*	η^2	*p*
MHI	1	1.677	.022	.199
Error	74			

Table C93

One-way ANOVA for MHI Status on Levels of Endorsed Sensation Seeking (UPPS-P)

Source	*df*	*F*	η^2	*p*
MHI	1	3.419	.044	.068
Error	74			

Table C94

Means and Standard Deviations for the UPPS-P Scale for Individuals with MHI and without MHI

UPPS-P Subscale	*Mean*	*Standard Deviation*
Impulsivity		
MHI	124.581	25.361
No MHI	127.825	21.673
Negative Urgency		
MHI	27.226	7.636
No MHI	28.477	6.673
Premeditation		
MHI	22.625	5.983
No MHI	22.442	5.369
Perseverance		
MHI	19.281	5.034
No MHI	20.273	4.385
Positive Urgency		
MHI	25.710	10.120
No MHI	28.711	9.797
Sensation Seeking		
MHI	37.032	7.472
No MHI	33.889	7.152

Table C95

One-way ANOVA for MHI Status on Levels of Endorsed Impulsivity (UPPS-P) Excluding Persons with a Psychiatric Condition

Source	*df*	*F*	η^2	*p*
MHI	1	.008	.000	.930
Error	58			

Table C96

One-way ANOVA for MHI Status on Levels of Endorsed Negative Urgency (UPPS-P) Excluding Persons with a Psychiatric Condition

Source	*df*	*F*	η^2	*p*
MHI	1	.732	.012	.395
Error	62			

Table C97

One-way ANOVA for MHI Status on Levels of Endorsed Premeditation (UPPS-P) Excluding Persons with a Psychiatric Condition

Source	*df*	*F*	η^2	*p*
MHI	1	.859	.013	.358
Error	62			

Table C98

One-way ANOVA for MHI Status on Levels of Endorsed Perseverance (UPPS-P) Excluding Persons with a Psychiatric Condition

Source	*df*	*F*	η^2	*p*
MHI	1	.393	.006	.533
Error	63			

Table C99

One-way ANOVA for MHI Status on Levels of Endorsed Positive Urgency (UPPS-P) Excluding Persons with a Psychiatric Condition

Source	*df*	*F*	η^2	*p*
MHI	1	.812	.013	.371
Error	63			

Table C100

One-way ANOVA for MHI Status on Levels of Endorsed Sensation Seeking (UPPS-P) Excluding Persons with a Psychiatric Condition

Source	*df*	*F*	η^2	*p*
MHI	1	5.809	.084	.019*
Error	63			

Note: *$p < .05$

Table C101

Means and Standard Deviations for the UPPS-P Scale for Individuals with MHI and without MHI Excluding Persons with a Psychiatric Condition

Impulsivity Subscale	*Mean*	*Standard Deviation*
Impulsivity		
MHI	126.346	24.706
No MHI	126.882	22.077
Negative Urgency		
MHI	26.653	7.132
No MHI	28.158	6.748
Premeditation		
MHI	23.444	5.767
No MHI	22.162	5.236
Perseverance		
MHI	19.037	4.903
No MHI	19.763	4.383
Positive Urgency		
MHI	26.385	9.753
No MHI	28.641	9.982
Sensation Seeking		
MHI	38.462	6.677
No MHI	34.256	7.029

Table C102

One-way ANOVA for MHI Status on Levels of Endorsed Aggression (BPAQ)

Source	*df*	*F*	η^2	*p*
MHI	1	2.689	.036	.105
Error	72			

Table C103

One-way ANOVA for MHI Status on Levels of Endorsed Anger (BPAQ)

Source	*df*	*F*	η^2	*p*
MHI	1	2.116	.029	.150
Error	74			

Table C104

One-way ANOVA for MHI Status on Levels of Endorsed Hostility (BPAQ)

Source	*df*	*F*	η^2	*p*
MHI	1	.048	.001	.828
Error	75			

Table C105

One-way ANOVA for MHI Status on Levels of Endorsed Verbal Aggression (BPAQ)

Source	*df*	*F*	η^2	*p*
MHI	1	1.317	.017	.255
Error	74			

Table C106

One-way ANOVA for MHI Status on Levels of Endorsed Physical Aggression (BPAQ)

Source	*df*	*F*	η^2	*p*
MHI	1	4.085	.052	.047*
Error	74			

Note: $*p < .05$

Table C107

Means and Standard Deviations for the BPAQ for Individuals with MHI and without MHI

BPAQ Subscale	*Mean*	*Standard Deviation*
Aggression		
MHI	76.833	19.543
No MHI	69.636	17.824
Anger		
MHI	17.719	6.770
No MHI	15.750	5.035
Hostility		
MHI	21.500	5.212
No MHI	21.222	5.692
Verbal Aggression		
MHI	15.548	4.073
No MHI	14.667	4.015
Physical Aggression		
MHI	22.516	8.414
No MHI	18.933	6.982

Table C108

One-way ANOVA for MHI Status on Levels of Endorsed Competitiveness (MC) Excluding Persons with a Psychiatric Condition

Source	*df*	*F*	η^2	*p*
MHI	1	6.348	.090	.014*
Error	64			

Note: **p* < .05

Table C109

One-way ANOVA for Athletic Status on Impulsivity (UPPS-P)

Source	*df*	*F*	η^2	*p*
Athletic Status	2	.502	.015	.608
Error	68			

Table C110

One-way ANOVA for Athletic Status on Negative Urgency (UPPS-P)

Source	*df*	*F*	η^2	*p*
Athletic Status	2	.981	.027	.380
Error	72			

Table C111

One-way ANOVA for Athletic Status on Premeditation (UPPS-P)

Source	*df*	*F*	η^2	*p*
Athletic Status	2	1.038	.028	.359
Error	72			

Table C112

One-way ANOVA for Athletic Status on Perseverance (UPPS-P)

Source	*df*	*F*	η^2	*p*
Athletic Status	2	1.078	.029	.346
Error	72			

Table C113

One-way ANOVA for Athletic Status on Positive Urgency (UPPS-P)

Source	*df*	*F*	η^2	*p*
Athletic Status	2	1.144	.031	.324
Error	72			

Table C114

One-way ANOVA for Athletic Status on Sensation Seeking (UPPS-P)

Source	*df*	*F*	η^2	*p*
Athletic Status	2	3.057	.077	.053
Error	72			

Table C115

Means and Standard Deviations for Impulsivity (UPPS-P) for Non-athletes, Low-risk Athletes, and High-risk Athletes

UPPS-P Subscale	*Mean*	*Standard Deviation*
Impulsivity Total		
Non-athlete	129.700	28.424
Low-risk Athlete	123.037	18.631
High-risk Athlete	127.458	23.659
Negative Urgency		
Non-athlete	29.625	8.350
Low-risk Athlete	27.222	5.899
High-risk Athlete	27.125	6.873
Premeditation		
Non-athlete	23.091	6.070
Low-risk Athlete	21.321	5.034
High-risk Athlete	23.360	5.765
Perseverance		
Non-athlete	23.091	6.070
Low-risk Athlete	21.321	5.034
High-risk Athlete	23.360	5.765
Positive Urgency		
Non-athlete	29.958	12.692
Low-risk Athlete	25.893	7.922
High-risk Athlete	26.875	8.931
Sensation Seeking		
Non-athlete	32.308	8.632
Low-risk Athlete	36.143	6.211
High-risk Athlete	37.000	6.705

Table C116

One-way ANOVA for Athletic Status on Aggression (BPAQ)

Source	*df*	*F*	η^2	*p*
Athletic Status	2	1.394	.034	.255
Error	71			

Table C117

One-way ANOVA for Athletic Status on Anger (BPAQ)

Source	*df*	*F*	η^2	*p*
Athletic Status	2	1.055	.028	.353
Error	73			

Table C118

One-way ANOVA for Athletic Status on Hostility (BPAQ)

Source	*df*	*F*	η^2	*p*
Athletic Status	2	.490	.013	.615
Error	74			

Table C119

One-way ANOVA for Athletic Status on Verbal Aggression (BPAQ)

Source	*df*	*F*	η^2	*p*
Athletic Status	2	1.299	.034	.279
Error	73			

Table C120

One-way ANOVA for Athletic Status on Physical Aggression (BPAQ)

Source	*df*	*F*	η^2	*p*
Athletic Status	2	.111	.058	.111
Error	73			

Table C121

Means and Standard Deviations for Aggression (BPAQ) for Non-athletes, Low-risk Athletes, and High-risk Athletes

Physiological Measure	*Mean*	*Standard Deviation*
Aggression Total		
Non-athlete	73.522	17.220
Low-risk Athlete	68.074	18.292
High-risk Athlete	76.667	20.291
Anger		
Non-athlete	17.957	5.440
Low-risk Athlete	15.751	5.763
High-risk Athlete	16.440	6.332
Hostility		
Non-athlete	22.500	5.024
Low-risk Athlete	20.821	5.722
High-risk Athlete	21.338	5.682
Verbal Aggression		
Non-athlete	14.917	3.933
Low-risk Athlete	14.037	3.828
High-risk Athlete	15.840	4.327
Physical Aggression		
Non-athlete	19.333	6.664
Low-risk Athlete	18.964	7.638
High-risk Athlete	23.125	8.456

Table C122

Hierarchical Multiple Regression Analysis of Number of MHIs Regressed on Athletic Status on Step 1 and Impulsivity (UPPS-P) on Step 2

	Variable	*B*	*sr*	*t*	*p*
1	Athletic Status	.266	.266	2.293	.025*
2	Athletic Status	.269	.269	2.313	.024*
	Impulsivity	.096	.096	.827	.411

Note: Overall R^2= .071; R^2= .080 for Step 1
Note: *p < .05

Table C123

Hierarchical Multiple Regression Analysis of Number of MHIs Regressed on Athletic Status on Step 1 and Aggression (BPAQ) on Step 2

	Variable	*B*	*sr*	*t*	*p*
1	Athletic Status	.284	.254	2.511	.014*
2	Athletic Status	.266	.223	2.419	.018*
	Aggression	.258	.280	2.344	.022*

Note: Overall R^2= .147; R^2= .081 for Step 1
Note: *p < .05

Table C124

Hierarchical Multiple Regression Analysis of Number of MHIs Regressed on Athletic Status on Step 1 and Competitiveness (MC) on Step 2

	Variable	*B*	*sr*	*t*	*p*
1	Athletic Status	.287	.287	2.595	.011*
2	Athletic Status	.196	.174	1.592	.116
	Competitiveness	.201	.179	1.637	.106

Note: Overall R^2= .082; R^2= .114 for Step 1
Note: *p < .05

Table C125

One-way ANOVA for MHI Status on Subjective Report of Arousal

Source	*df*	*F*	η^2	*p*
MHI	1	.276	.003	.601
Error	75			

Table C126

One-way ANOVA for MHI Status on Respiration Band 1 (CPM)

Source	*df*	*F*	η^2	*p*
MHI	1	.487	.007	.487
Error	73			

Table C127

One-way ANOVA for MHI Status on Respiration Band 2 (CPM)

Source	*df*	*F*	η^2	*p*
MHI	1	.559	.008	.457
Error	73			

Table C128

One-way ANOVA for MHI Status on Pulse Amplitude

Source	*df*	*F*	η^2	*p*
MHI	1	.252	.003	.617
Error	73			

Table C129

One-way ANOVA for MHI Status on Pulse (CPM)

Source	*df*	*F*	η^2	*p*
MHI	1	.121	.002	.729
Error	73			

Table C130

One-way ANOVA for MHI Status on HRV

Source	*df*	*F*	η^2	*p*
MHI	1	.227	.000	.635
Error	73			

Table C131

One-way ANOVA for MHI Status on Pulse (CPM) Without Outliers

Source	*df*	*F*	η^2	*p*
MHI	1	2.443	.033	.123
Error	71			

Table C132

One-way ANOVA for MHI Status on Systolic Blood Pressure

Source	*df*	*F*	η^2	*p*
MHI	1	1.339	.018	.251
Error	75			

Table C133

A 2 (MHI Status) X 2 (Sex) ANOVA for Systolic Blood Pressure

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	.072	.001	.789
Sex	1	14.614	.200	.001***
MHI X Sex	1	.450	.006	.505
Error	73			

Note: ***$p <$ .001

Table C134

One-way ANOVA for MHI Status on Diastolic Blood Pressure

Source	*df*	*F*	η^2	*p*
MHI	1	.025	.000	.875
Error	75			

Table C135

Means and Standard Deviations for Physiological Measures for Individuals with MHI and without MHI

Physiological Measure	*Mean*	*Standard Deviation*
Respiration 1		
MHI	13.904	3.095
No MHI	14.520	4.166
Respiration 2		
MHI	13.945	2.931
No MHI	14.595	4.169
Pulse (amplitude)		
MHI	.857	.306
No MHI	.824	.278
Pulse (CPM)		
MHI	71.188	14.418
No MHI	72.238	11.691
HRV		
MHI	.063	.034
No MHI	.066	.034
Pulse (CPM; without outliers)		
MHI	68.271	1.615
No MHI	72.238	1.763
Systolic Blood Pressure		
MHI	112.250	12.934
No MHI	107.422	20.903
Diastolic Blood Pressure		
MHI	69.813	7.965
No MHI	69.533	7.446

Table C136

A 2 (MHI Status) X 3 (Athletic Status) ANOVA for EDA Amplitude

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	3.134	.040	.081
Athletic Status	2	.319	.008	.728
MHI X Athletic Status	2	1.125	.028	.330
Error	70			

Table C137

Means and Standard Deviations for EDA Amplitude for MHI and Athletic Status

Physiological Measure	*Mean*	*Standard Deviation*
No MHI		
Non-athlete	1.634	1.848
Low-risk Athlete	2.151	2.162
High-risk Athlete	1.447	.520
MHI		
Non-athlete	1.538	.929
Low-risk Athlete	.587	.804
High-risk Athlete	.891	.822
Athletic Status Total		
Non-athlete	1.610	1.648
Low-risk Athlete	1.760	2.020
High-risk Athlete	1.030	.787
MHI Status Total		
MHI	.947	.871
No MHI	1.850	1.887

Table C138

A 2 (MHI Status) X 3 (Time Interval) Between Subjects Repeated Measures ANOVA for EDA amplitude at Minute 1, 2, and 3

Source	*df*	*F*	η^2	*p*
Between Subjects				
MHI	1	4.450	.063	.038*
Error	71			

Note: *$p < .05$

Table C139

Means and Standard Deviations EDA amplitude for Individuals with MHI and without MHI

Physiological Measure	*Mean*	*Standard Deviation*
EDA Minute 1		
MHI	2.073	.786
No MHI	3.551	.657
EDA Minute 2		
MHI	1.625	.278
No MHI	2.132	.232
EDA Minute 3		
MHI	1.707	.582
No MHI	2.806	.486

Table C140

Hierarchical Multiple Regression Analysis of EDA Amplitude Regressed on Impulsivity (UPPS-P) on Step 1, Athletic Status on Step 2, and MHI Status on Step 3

	Variable	*B*	*sr*	*t*	*p*
1	Impulsivity	-.048	-.048	-.397	.693
2	Impulsivity	-.054	-.054	-.448	.656
	Athletic Status	-.149	-.149	-1.235	.221
3	Impulsivity	-.072	-.072	-.614	.542
	Athletic Status	-.048	-.045	-.386	.701
	MHI Status	-.283	-.264	-2.251	.028*

Note: Overall R^2= .094; R^2= .002 for Step 1; R^2= .025 for Step 2
*p < .05

Table C141

Hierarchical Multiple Regression Analysis of EDA Amplitude Regressed on Negative Urgency (UPPS-P) on Step 1, Athletic Status on Step 2, and MHI Status on Step 3

	Variable	*B*	*sr*	*t*	*p*
1	Negative Urgency	-.050	-.050	-.427	.670
2	Negative Urgency	-.074	-.073	-.625	.534
	Athletic Status	-.159	-.157	-1.343	.184
3	Negative Urgency	-.084	-.083	-.728	.469
	Athletic Status	-.051	-.047	-.409	.684
	MHI Status	-.278	-.225	-2.240	.028*

Note: Overall R^2= .092; R^2= .003 for Step 1; R^2= .027 for Step 2
*p < .05

Table C142

Hierarchical Multiple Regression Analysis of EDA Amplitude Regressed on Premeditation (UPPS-P) on Step 1, Athletic Status on Step 2, and MHI Status on Step 3

	Variable	*B*	*sr*	*t*	*p*
1	Premeditation	-.013	-.013	-.111	.912
2	Premeditation	-.012	-.012	-.100	.920
	Athletic Status	-.136	-.136	-1.156	.252
3	Premeditation	-.013	-.013	-.109	.913
	Athletic Status	-.034	-.031	-.271	.787
	MHI Status	-.263	-.242	-2.112	.038*

Note: Overall R^2= .077; R^2= .000 for Step 1; R^2= .019 for Step 2
*p < .05

Table C143

Hierarchical Multiple Regression Analysis of EDA Amplitude Regressed on Perseverance (UPPS-P) on Step 1, Athletic Status on Step 2, and MHI Status on Step 3

	Variable	*B*	*sr*	*t*	*p*
1	Perseverance	.123	.123	1.063	.291
2	Perseverance	.103	.012	.880	.382
	Athletic Status	-.126	-.125	-1.076	.382
3	Perseverance	.090	.089	.781	.437
	Athletic Status	-.027	-.025	-.219	.828
	MHI Status	-.256	-.234	-.2066	.043*

Note: Overall R^2= .086; R^2= .015 for Step 1; R^2= .031 for Step 2
*p < .05

Table C144

Hierarchical Multiple Regression Analysis of EDA Amplitude Regressed on Positive Urgency (UPPS-P) on Step 1, Athletic Status on Step 2, and MHI Status on Step 3

	Variable	*B*	*sr*	*t*	*p*
1	Positive Urgency	-.032	-.032	-.271	.787
2	Positive Urgency	-.048	-.047	-.407	.661
	Athletic Status	-.148	-.147	-1.265	.192
3	Positive Urgency	-.080	-.079	-.692	.437
	Athletic Status	-.048	-.044	-.319	.828
	MHI Status	-.276	-.254	-2.241	.028*

Note: Overall R^2= .087; R^2= .001 for Step 1; R^2= .024 for Step 2
*p < .05

Table C145

Hierarchical Multiple Regression Analysis of EDA Amplitude Regressed on Sensation Seeking (UPPS-P) on Step 1, Athletic Status on Step 2, and MHI Status on Step 3

	Variable	*B*	*sr*	*t*	*p*
1	Sensation Seeking	-.241	-.241	-2.120	.037*
2	Sensation Seeking	-.217	-.209	-1.834	.071
	Athletic Status	-.090	-.087	-.760	.450
3	Sensation Seeking	-.188	-.179	-1.606	.113
	Athletic Status	-.004	-.003	-.029	.977
	MHI Status	-.240	-.219	-1.958	.054

Note: Overall R^2= .113; R^2= .058 for Step 1; R^2= .065 for Step 2
*p < .05

Table C146

Hierarchical Multiple Regression Analysis of EDA Amplitude Regressed on Aggression (BPAQ) on Step 1, Athletic Status on Step 2, and MHI Status on Step 3

	Variable	*B*	*sr*	*t*	*p*
1	Aggression	-.241	-.241	-2.095	.040*
2	Aggression	-.231	-.233	-2.008	.049*
	Athletic Status	-.145	-.150	-1.265	.210
3	Aggression	-.195	-.199	-.1689	.096
	Athletic Status	-.063	-.062	-.516	.608
	MHI Status	-.219	-.207	-1.754	.084

Note: Overall R^2= .119; R^2= .058 for Step 1; R^2= .079 for Step 2
*p < .05

Table C147

Hierarchical Multiple Regression Analysis of EDA Amplitude Regressed on Physical Aggression (BPAQ) on Step 1, Athletic Status on Step 2, and MHI Status on Step 3

	Variable	*B*	*sr*	*t*	*p*
1	Physical Aggression	-.295	-.295	-2.642	.010*
2	Physical Aggression	-.277	-.271	-2.416	.018*
	Athletic Status	-.091	-.089	-.793	.430
3	Physical Aggression	-.240	-.232	-2.099	.039*
	Athletic Status	-.012	-.011	-.100	.920
	MHI Status	-.220	-.199	-1.804	.075

Note: Overall R^2= .135; R^2= .087 for Step 1; R^2= .095 for Step 2
*p < .05

Table C148

Hierarchical Multiple Regression Analysis of EDA Amplitude Regressed on Verbal Aggression (BPAQ) on Step 1, Athletic Status on Step 2, and MHI Status on Step 3

	Variable	*B*	*sr*	*t*	*p*
1	Verbal Aggression	-.245	-.245	-2.155	.034*
2	Verbal Aggression	-.232	-.231	-2.041	.045*
	Athletic Status	-.122	-.122	-1.072	.287
3	Verbal Aggression	-.211	-.208	-1.867	.066
	Athletic Status	-.033	-.030	-.267	.791
	MHI Status	-.255	-.204	-1.827	.072

Note: Overall R^2= .116; R^2= .060 for Step 1; R^2= .075 for Step 2
*$p < .05$

Table C149

Hierarchical Multiple Regression Analysis of EDA Amplitude Regressed on Anger (BPAQ) on Step 1, Athletic Status on Step 2, and MHI Status on Step 3

	Variable	*B*	*sr*	*t*	*p*
1	Anger	-.017	-.061	-.523	.603
2	Anger	-.021	-.077	-.654	.508
	Athletic Status	-.335	-.165	-1.419	.160
3	Anger	-.066	-.022	-.191	.849
	Athletic Status	-.015	-.015	-.450	.654
	MHI Status	-.850	-.233	-2.053	.044*

Note: Overall R^2= .085; R^2= .004 for Step 1; R^2= .031 for Step 2
*p < .05

Table C150

Hierarchical Multiple Regression Analysis of EDA Amplitude Regressed on Hostility (BPAQ) on Step 1, Athletic Status on Step 2, and MHI Status on Step 3

	Variable	*B*	*sr*	*t*	*p*
1	Hostility	-.262	-.262	-2.339	.022*
2	Hostility	-.279	-.278	-2.498	.015*
	Athletic Status	-.171	-.171	-1.535	.129
3	Hostility	-.265	-.263	-2.419	.018*
	Athletic Status	-.071	-.065	-.597	.552
	MHI Status	-.244	-.233	-2.045	.044*

Note: Overall R^2= .147; R^2= .069 for Step 1; R^2= .098 for Step 2
*p < .05

Table C151

Hierarchical Multiple Regression Analysis of EDA Amplitude Regressed on Competitiveness (MC) on Step 1, Athletic Status on Step 2, and MHI Status on Step 3

	Variable	*B*	*sr*	*t*	*p*
1	Competitiveness	-.165	-.165	-1.443	.153
2	Competitiveness	-.126	-.122	-.975	.333
	Athletic Status	-.087	-.078	-.676	.501
3	Competitiveness	-.083	-.073	-.647	.520
	Athletic Status	-.006	-.005	-.047	.963
	MHI Status	-.244	-.224	-.1984	.051

Note: Overall R^2= .084; R^2= .027 for Step 1; R^2= .033 for Step 2

Table C152

Hierarchical Multiple Regression Analysis of Post-season SDMT Score Regressed on Pre-season SDMT Score on Step 1 and MHI Status on Step 2

	Variable	*B*	*sr*	*t*	*p*
1	Pre-season SDMT	.799	.799	10.471	.000***
2	Pre-season SDMT	.789	.787	10.580	.000***
	MHI Status	.154	.153	2.059	.044**

Note: Overall R^2= .662; R^2= .639 for Step 1
*p < .05
***p < .001

Table C153

Hierarchical Multiple Regression Analysis of Post-season LNS Score Regressed on Pre-season LNS Score on Step 1 and MHI Status on Step 2

	Variable	*B*	*sr*	*t*	*p*
1	Pre-season LNS	.422	.422	3.662	.001***
2	Pre-season LNS	.417	.416	3.599	.001***
	MHI Status	.088	.088	.762	.449

Note: Overall R^2= .186; R^2= .178 for Step 1
***p < .001

Table C154

Hierarchical Multiple Regression Analysis of Post-season TMT-III Time Regressed on Pre-season TMT-II Time on Step 1 and MHI Status on Step 2

	Variable	*B*	*sr*	*t*	*p*
1	Pre-season TMT-II	.652	.652	6.762	.000***
2	Pre-season TMT-II	.654	.650	6.688	.000***
	MHI Status	.019	.024	.190	.850

Note: Overall R^2= .425; R^2= .424 for Step 1
***p < .001

Table C155

Hierarchical Multiple Regression Analysis of Post-season TMT-IV Time Regressed on Pre-season TMT-IV Time on Step 1 and MHI Status on Step 2

	Variable	*B*	*sr*	*t*	*p*
1	Pre-season TMT-IV	.530	.530	4.921	.000***
2	Pre-season TMT-IV	.536	.535	4.966	.000***
	MHI Status	-.102	-.102	-.944	.349

Note: Overall R^2= .281; R^2= .281 for Step 1
***p < .001

Table C156

Hierarchical Multiple Regression Analysis of Post-season EDA Amplitude Regressed on Pre-season EDA Amplitude on Step 1 and MHI Status on Step 2

	Variable	*B*	*sr*	*t*	*p*
1	EDA Amplitude	.257	.257	1.971	.054
2	EDA Amplitude	.277	.276	2.155	.036*
	MHI Status	.277	.226	1.766	.083

Note: Overall R^2= .425; R^2= .424 for Step 1
Note: *p < .05

Table C157

Hierarchical Multiple Regression Analysis of Post-season Impulsivity (UPPS-P) Regressed on Pre-season Impulsivity on Step 1 and MHI Status on Step 2

	Variable	*B*	*sr*	*t*	*p*
1	Impulsivity	.769	.769	8.510	.000***
2	Impulsivity	.780	.777	8.705	.000***
	MHI Status	.133	.133	1.484	.144

Note: Overall R^2= .592; R^2= .609 for Step 1
Note: ****p* < .001

Table C158

Hierarchical Multiple Regression Analysis of Post-season Aggression (BPAQ) Regressed on Pre-season Aggression on Step 1 and MHI Status on Step 2

	Variable	*B*	*sr*	*t*	*p*
1	Aggression	.872	.872	13.591	.000***
2	Aggression	.870	.855	13.216	.000***
	MHI Status	.015	.015	.235	.815

Note: Overall R^2= .761; R^2= .761 for Step 1
Note: ****p* < .001

Table C159

Hierarchical Multiple Regression Analysis of Post-season Competitiveness (MC) Regressed on Pre-season Competitiveness on Step 1 and MHI Status on Step 2

	Variable	*B*	*sr*	*t*	*p*
1	Competitiveness	.917	.917	17.693	.000***
2	Competitiveness	.891	.830	16.095	.000***
	MHI Status	.071	.066	1.286	.204

Note: Overall R^2= .846; R^2= .841 for Step 1
Note: ***p < .001